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BY THE COMPTROLLER GENERAL

Report To The Congress

OF THE UNITED STATES

AD A090520

(6) Are Management Problems In The Acquisition Of Aircraft Gas Turbine Engines Being Corrected?

Problems in fighter/attack aircraft engines have been largely due to inadequate development concepts and procedures. Because the problems have been particularly costly and highly visible, the Navy and the Air Force have adopted new concepts and procedures which they are incorporating into formal policy, specification, and procedural documents. However, the standards, data base, and analytical procedures to implement the new concepts either have not been developed or have been incomplete.

The question is less what should be done, and more how and when it will be done? Answers to this question depend on top-level understanding, support, and direction within the services and the Office of the Secretary of Defense.

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COMPTROLLER GENERAL OF THE UNITED STATES
WASHINGTON, D.C. 20548

B-198346

To the President of the Senate and the
Speaker of the House of Representatives

This report describes management problems in the acquisition of gas turbine engines for fighter/attack aircraft. It assesses corrective actions taken and promised. Its purpose is to provide information the Congress needs to carry out its oversight responsibilities in this increasingly important and costly area.

We are sending copies of the report to the Director, Office of Management and Budget, and the Secretaries of Defense, Air Force, and Navy.

Elmer B. Staats
Comptroller General
of the United States

COMPTROLLER GENERAL'S
REPORT TO THE CONGRESS

ARE MANAGEMENT PROBLEMS IN THE ACQUISITION OF AIRCRAFT GAS TURBINE ENGINES BEING CORRECTED?

D I G E S T

Recent problems with fighter/attack aircraft engines have been primarily due to development concepts, procedures, and practices that did not provide the time and money to (1) adequately develop the engines before production and use and (2) bring promising technology up to the point that it was ready for applications in new engines. Other major factors that adversely affected engine development were

--inadequate definition of the engines' usage and, consequently, the inability to design engines to their expected usage and to verify the design by testing to that usage;

--emphasis on performance requirements with a resulting lack of standards, data base, and analytical procedures to achieve a balance among performance, operability, reliability, durability, and costs; and

--inadequate flight testing of engines.

The cumulative result has been incomplete development before production, especially in regard to the engines' reliability, maintainability, and durability. Incomplete development, in turn, has resulted in extensive Component Improvement Programs (CIPs), increased spare parts costs, reduced operational readiness, and expensive retrofits.

F100 ENGINE DEVELOPMENT

Air Force performance requirements for the F100 engines, on F-15 aircraft, required application of promising but unproven technology that could not be fully developed within the $457 million, 6-year development program. Inadequate definition of the engine's usage, emphasis on performance requirements, and inadequate flight testing also contributed to incomplete engine development before production. As a result, the F-15 experienced engine problems that have

adversely affected fleet operational readiness and increased spare parts costs by $147 million. From 1974 to 1984, the Air Force will nave spent about $665 million on CIPs to correct the problems. Although the costs to make improvements that may result from the CIPs could not be determined, the service estimates about $109 million for known improvements to its growing inventory of F100 engines through fiscal year 1981. (See pp. 8 to 11.)

F401 ENGINE DEVELOPMENT

Development of F401 engines for the Navy's F-14 was initiated in a joint program with the Air Force's development of the F100. The F401 was a larger version of the F100 engine and, like the F100, required the application of technology that could not be adequately developed within the program's funding and schedule constraints. The program was suspended in 1973 because of reported engine failures and funding constraints. The Navy states that it spent $369 million on developing the F401. (See pp. 11 and 12.)

TF30 ENGINE MODIFICATION

The TF30 engine, used on the F-111 aircraft, was to be modified for use as an interim engine on the first 33 F-14 aircraft. Development problems and subsequent suspension of the F401 engine program resulted in the use of the TF30 engine on all F-14s. To meet the F-14 airframe production schedule, modification of the TF30 engine was limited to 2 years and 5 months at a cost of $21 million. The specification for the TF30/F-14 engine excluded requirements for durability, reliability, and maintainability in spite of the operational problems experienced on the F-111. The engine was approved for production before many durability problems exhibited during qualification tests were corrected. Further, the contractor was not given mission profiles upon which to base the engine design modification until May 1972, 1 year after completing development. From the start of the engine's production in 1971 through 1985, the Navy will have spent about $840 million in developing and installing engine

modifications to correct safety of flight and durability problems. (See pp. 12 to 15.)

TF34 ENGINE MODIFICATION

Modification of the TF34 engine, used on the Navy's S-3A aircraft, to fit the Air Force's A-10 aircraft was a 2-year, 3-month effort that cost $14.5 million. The development period did not provide time to resolve several engine problems before production, and shortcuts were taken to reduce development testing. The Air Force version and its Navy predecessor continue to experience durability problems. By 1983, the Navy and Air Force will have spent about $210 million on CIPs for this engine. (See pp. 15 to 17.)

IMPROVEMENTS IN ENGINE DEVELOPMENT

Because of the extensive and costly F100 and TF30 problems that will extend into the mid-1980s and possibly longer, the services have implemented or are implementing the following improvements in engine development programs and CIPs:

--Better definition of missions and usage requirements.

--Emphasis on establishing structural integrity requirements.

--Expanded ground and flight testing before full-scale production.

--New emphasis on accelerated mission-type testing and accelerated flight schedules to identify usage problems so they can be corrected early in the operational phase.

These improvements represent a new approach to engine development that provides more time and money to reach Initial Operational Capability dates than was provided in the past. (See p. 19.)

The recent improvements are also present in CIPs and require additional funds to support accelerated mission tests and accelerated

flight programs. During fiscal year 1979 the Air Force was not achieving the utilization rate required by its F100 accelerated flight program, and consequently deficiencies may not be identified in time to develop corrective actions before the problems appear on the balance of engines in the inventory. (See pp. 26 and 27.)

The Navy does not have accelerated flight programs but instead performs trend analysis of engines inducted into the depot for repair/rework which are then correlated to the results of accelerated simulated mission endurance tests run on test stands.

STATUS OF NEW DEVELOPMENT CONCEPTS

The services' new approaches to engine development are being incorporated into formal policy, specification, and procedural documents. (See pp. 30 to 34.) However, actions to minimize technology constraints and fully implement the new development concepts are incomplete or have not been taken.

In the area of technology constraints, advanced development (technology demonstrator) programs have been consistently underfunded for structural testing of new designs and technology. Although the Congress appropriated $25 million above budget for durability-type testing during fiscal year 1980, the services' requests for fiscal year 1981 may not sustain the congressional initiative. If adequately supported, structural testing in the technology demonstrator programs could improve the technology base and risk assessment for new engine programs and result in less development failures, less costs, and shorter development times. (See pp. 36 to 41.)

Other key improvements needed to implement the new development concepts are development of a management standard, data base, and analytical procedures to identify and measure cost effectiveness of engines, systematic methods for reviewing and updating engine usage requirements and experience, and a system for tracking engineering changes. (See pp. 42 to 45.)

The above improvements would better enable advocates of the new approaches to

--quantify benefits and justify the additional testing and lengthening of the engine development process required by the new approaches;

--minimize the increased development time and costs by making the long empirical, iterative design process more rational and analytical; and

--improve contractor incentives by enabling the Government to specify logistical requirements in contractural terms. (Contractor incentives are discussed on pp. 45 to 48.)

RECOMMENDATIONS TO THE SECRETARY OF DEFENSE

GAO recommends that the Secretary of Defense delegate specific responsibility to an organization within his Office to direct and supervise the Air Force and Navy efforts to establish an organized and disciplined approach to the structural design, analysis, development, production, and life management of aircraft gas turbine engines. The designated organization should require the services to

--complete the formalization of their new policies, principles, and procedures for engine acquisition management by way of regulations and other appropriate documents;

--establish a master plan for developing the standards, supporting methodology, data base, and analytical procedures needed to fully implement the policies and principles and make the development process more rational and analytical;

--realine funding priorities to expand and improve advanced development programs in general and structural testing and development in particular; and

--coordinate their improvement efforts so as to enhance and encourage joint acquisition programs.

The designated organization should closely monitor the F101 Derivative Fighter Engine and Advanced Technology Engine joint programs. The Advanced Technology Engine program could be used as a pilot program to test and refine the services' new engine acquisition management concepts and to further develop and refine data collection and analytical procedures needed to produce more mature and cost-effective engines before full-scale production.

Because of the Congress' interest in the Air Force's and Navy's development and life management of aircraft gas turbine engines, GAO recommends that the Secretary of Defense periodically report to the Congress on its progress and problems in developing an organized and disciplined approach to the life management of aircraft gas turbine engines. The report should spell out the impact of the new approach on existing programs--CIPs, F101 Derivative Figher Engine, and Advance Technology Engine--to provide the Congress information it needs to carry out its oversight responsibilities and to lessen its need to get more deeply involved in the Department of Defense's management of engine programs. The reporting could be made part of the annual authorization and appropriation hearings.

AGENCY AND CONTRACTOR COMMENTS

The Department of Defense and one of the two engine contractors invited to respond generally agreed with the facts and conclusions presented. (See pp. 54 and 55.) Defense, however, objected to GAO's recommendation for periodic reporting to the Congress on progress and problems in developing a new approach to the life management of aircraft gas turbines. Defense stated the current requirements for providing information to the Congress are sufficient. As explained on page 54, GAO believes that such reporting is warranted because of an expressed congressional interest in a more disciplined management approach and the need for Defense to demonstrate such an approach to

obtain timely and adequate support for future engine programs.

The contractor expressed concern that the study did not include some of the broader policy options and trade-offs that could be considered in engine development and raised questions about trade-offs in the acquisition of engines that should be made from a benefit/risk standpoint. GAO agrees that the greatest hindrances to engine development are time and money constraints and that deviations from an optimal engine development approach can be justified. This report is, however, geared toward the establishment of an organized and disciplined approach to the life management of aircraft gas turbine engines and not toward situations in which justifiable deviations can be allowed.

Contents

ABBREVIATIONS

AMT	accelerated mission test
APSI	Aircraft Propulsion Subsystem Integration
ASMET	accelerated simulated mission endurance test
ATE	Advanced Technology Engine
ATEGG	Advanced Turbine Engine Gas Generator
CIP	Component Improvement Program
DFE	Derivative Fighter Engine
DOD	Department of Defense
ENSIP	Engine Structural Integrity Program
GAO	General Accounting Office
LTF	Lead-the-Force
PFRT	preliminary flight rating test
SMET	simulated mission endurance test

CHAPTER 1

INTRODUCTION

The Air Force and the Navy's aircraft gas turbine engine acquisition process is a major undertaking involving more than a billion dollars each year. The acquisition process includes the design, development, procurement, and operational support of thousands of gas turbine engines. In 1976 the Air Force's active inventory alone consisted of 38,000 aircraft propulsion units. These engines represented a total investment of $10 billion in 1975 dollars and required an expenditure of $500 million annually for their logistical support.

The dollar significance of the acquisition process is illustrated by a Navy study estimate of certain engines' life cycle costs. The engines were estimated to account for 30 percent, and their fuel 10 percent, of the typical twin-engine fighter/attack aircraft's life cycle cost; the airframe and avionics account for the remaining 60 percent. Navy study estimates of life cycle costs for engines and their fuel over a 25-year period on the following twin-engine aircraft are:

Aircraft	Engine	Engine life cycle cost (incl. fuel)
		(billions in 1978 dollars)
F-14	TF30	$ 9.1
F-4	J79	5.7
A-7	TF41	5.2
Total		$20.0

The gas turbine engine has made remarkable progress in its generic development over the past 30 years.

--Performance improvements in engine thrust-to-weight ratio technology have increased more than fivefold from the 1945 vintage J33 turbojet engine to the 1975 F100 turbofan engine.

--Thrust specific fuel consumption for the TF39, the largest military turbofan engine, is 70 percent better than the early model J33.

--The maximum operating time improvements for fighter-type engines are currently several orders of magnitude better than their early predecessors.

Technological changes are dramatically illustrated by comparing the J79 engine on the F-4 aircraft with the F404 engine on the F-18 aircraft. Both are engines on fighter/attack aircraft, with the J79 turbojet engine being military qualified in 1962 and the F404 turbofan engine in 1979--a time span of 17 years. As shown in figure 1, the engines produce about the same amount of thrust, but the F404 engine is much smaller in size and weight and has one-third fewer parts. Because of the decrease in weight, the F404 engine has a thrust-to-weight ratio of about 8 to 1, whereas the J79 engine has a ratio of 4.6 to 1.

In achieving the technology advancements, the mechanical complexity of the engines has increased many times over the years. Some observers have felt that the engine acquisition process has not kept pace. Recent operational problems with high performance fighter engines--the F100 engines in the Air Force's F-15 fighter aircraft and the TF30 engines in the Navy's F-14 fighter aircraft--have reinforced this conception.

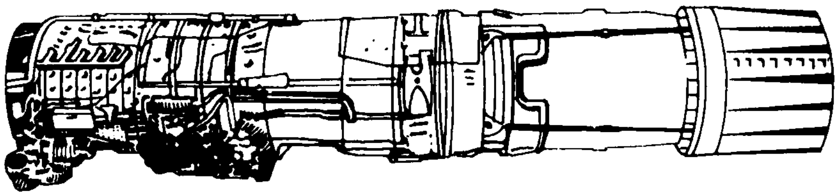
The seriousness of the problems, their cost and impact on the operational readiness of the Navy's and the Air Force's two top-line fighters, prompted us to review the engine acquisition and development process to identify areas where improvements could be made. Since the technical problems and some of their proposed solutions had been extensively discussed during fiscal years 1978 and 1979 congressional hearings, our review was directed primarily toward the management of the acquisition processes.

A preliminary survey noted that many studies on various aspects of the gas turbine engine acquisition process had been completed over the past 10 years. We are particularly indebted to the Air Force's Scientific Advisory Board reports issued in August 1973 and January 1976 and the Defense Procurement Management Review report issued in February 1976 for better understanding of the acquisition process as it existed before 1976. These informative studies are referred to in this report, and the major findings and recommendations of the 1976 Defense Procurement Management Review report are included as appendix I.

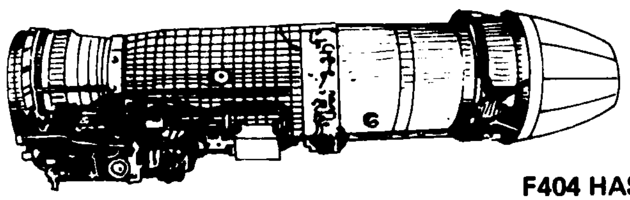
OBJECTIVES, SCOPE, AND METHODOLOGY

The objective of our review was to examine in broad perspective the Department of Defense's (DOD's) management approach to the acquisition of high technology turbine engines. Our review examined seven specific engine development programs initiated or completed during the past 10

F404 VERSUS J79 COMPARISON



J79



F404

F404 HAS THE SAME THRUST WITH
- ½ the Weight
- ¾ the Length
- 7,700 Fewer Parts
- 7 Fewer Turbomachinery Stages
- 11% Smaller Diameter
- 14% Less Airflow

years involving Air Force and Navy gas turbine engines for fighter/attack-type aircraft.

The seven engines and engine contractors are:

Contractors	Engines	Aircraft
Pratt & Whitney Aircraft	F100	F-15/F-16
Pratt & Whitney Aircraft	F401	F-14B
Pratt & Whitney Aircraft	TF30	F-14A
General Electric	TF34	A-10
General Electric	F404	F-18
General Electric	F-101DFE	F-14/F-16
Multiple contractors	Advanced Technology Engine (ATE)	-

We examined deficiencies in the two services' acquisition management that contributed significantly to current engine problems and assessed corrective actions taken and promised based on "lessons learned" and recommendations from previous turbine engine studies.

Our review was performed at the (1) U.S. Aero Propulsion Laboratory and the Deputy for Propulsion, Wright-Patterson Air Force Base, Ohio, (2) the Arnold Engineering Development Center, Arnold Air Force Station, Tennessee, (3) offices in the Naval Air Systems Command, Washington, D.C., (4) Naval Air Propulsion Center, Trenton, New Jersey, (5) General Electric Company Aircraft Engine Groups, Lynn, Massachusetts, and Cincinnati, Ohio, and (6) United Technologies Corporation, Pratt & Whitney Aircraft Group, West Palm Beach, Florida. We interviewed technical, contracting, and financial officials at each location, including representatives in the F-14, F-15, F-16, and F-18 program offices and examined pertinent studies, contracts, program plans, schedules, and other documents.

CHAPTER 2

RECENT ENGINE PROBLEMS

Recent engine problems with fighter/attack aircraft have been primarily management related. The problems were due largely to development concepts, procedures, and practices that did not recognize the "facts of engine development life." 1/ That is, they did not provide the time and money needed (1) to adequately develop the engines before their production and operational deployment and (2) in new engine developments to bring promising technology up to the point that it was ready for systems applications. Following are some other major factors.

--Inadequate definition of the systems' missions and engine usage and, consequently, inability to design the engines to the expected usage and to verify the design by testing to the usage.

--Emphasis on performance requirements with a resulting lack of standards, data base, and analytical procedures to achieve a balance among performance, operability, reliability, durability, and costs.

--Inadequate flight testing of the engines not only because of time and cost constraints but because the engines were considered subsystems and flight test plans were not directed at engine performance per se.

The cumulative result has been incomplete development of the engines before production, especially regarding the engines' reliability, maintainability, and durability. Incomplete development, in turn, has resulted in extensive Component Improvement Programs (CIPs), increased spare parts costs, reduced operational readiness, and costly retrofits.

FACTS OF ENGINE DEVELOPMENT LIFE NOT RECOGNIZED

Air Force representatives acknowledge that developing a new engine takes 9 to 15 years from initial idea to

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1/Term used in a 1973 report of the Air Force Scientific Advisory Board, an ad hoc committee on engine development, to discuss a few fundamental facts of engine development that must be recognized and properly included in a system development cycle.

full-scale production. More specifically, the Air Force's proposed new concept for engine development assumes a 1- to 5-year conceptual study effort and suggests as a guideline a period of 2-3/4 to 3-3/4 years for validation and 5 to 6 years for full-scale development. The Scientific Advisory Board's ad hoc committee on engine development explained the long development period on the basis that new engines are only justified as major extensions of technology and that engine development is still an empirical process of design, build, test, fail, and redesign which repeats itself until an acceptable engine is demonstrated.

Air Force representatives also acknowledge that modifications to existing engines which are evolutionary extensions of technology may require half the development time of a new engine--from 5 to 7 years. The Scientific Advisory Board observed that if an existing engine is modified enough, however, it can exhibit all the difficulties of a new engine and require the longer iterative development process for a new engine.

The following schedule shows the development time and resources the services have provided, or plan to provide, before full-scale production of the engines covered by our review. Also shown is the funding provided, or to be provided, for continuing development--CIPs--following production releases. The new technology required is indicated by whether the program is to develop a new engine or modify an existing engine and by the engines' thrust-to-weight ratios.

Engine designation/ applications	Development classification/ thrust-to-weight	Development Time	Development Funds	CIP funds thru 1984 (note a)
		(years)	-------(millions)	-------
F100/F-15, F-16	New/8 to 1	6	$ 457	$665
F401/F-14B	New/8 to 1	5	369	b/Suspended
F404/F/A-18	New/8 to 1	10	c/336	148
ATE/Multiple applications in 1990s	New/10 to 1	11-12	1,245	In development to 1990
TF30/F-14A	Mod./5 to 1	2.4	21	d/289
TF34/A-10	Mod./6 to 1	2.3	15	e/210
F101DEF/F-14, F-16	Mod./7 to 1	4.5	f/548	Contingent on production decision

a/Does not include costs of incorporating improvements on engines.

b/Develoment suspended in Dec. 1973 because of engine failures during testing and lack of funding.

c/Full-scale development only. Does not include costs for YJ101/YF-17 validation and demonstration program.

d/From 1971 through 1981. Does not include over $552 million to incorporate improvements on existing engines from 1982-86.

e/Includes estimated Navy and Air Force CIP funds for TF34 engine through 1983.

f/Does not include F101 (B-1) development costs of $621 million. Only a 30-month, $93 million limited development program has been approved. Full-scale engineering development of an engine for F-14 and F-16 application is estimated to cost about $455 million.

The above schedule shows that development time for the Air Force's F100 and TF34 engines and the Navy's F401 and TF30 engines has been much less than the Air Force's suggested guidelines of 9 to 15 years for new engines and 5 to 7 years for modified engines. Except for the F401 program, which was suspended before production, the postproduction development funds (CIP funds) for the engines have exceeded the preproduction development funds, in most cases, by substantial margins. These individual engine programs are discussed in the following sections.

The schedule also shows that new programs--F404 engine, ATE, and F101DFE engine--are being given more development time and resources. Changes being made in these engine development programs are discussed in chapter 3.

F100 ENGINE DEVELOPMENT

In December 1967 the Air Force initiated development of a new high performance turbofan engine for its experimental F-15 fighter. The new engine was to generate 40 percent more thrust (in excess of 20,000 pounds) and weigh 25 percent less than the TF30 engine in the F-111. The engine was to have a 9 to 1 thrust-to-weight ratio. To meet these major extensions in performance requirements, the contractor was to use new lightweight materials and new improved designs for more efficient compressor stage loading and high turbine temperatures.

The ambitious performance goals used to justify the new engine's development appeared realistic based on experience gained from technology demonstrator programs. These programs concentrated on demonstrating performance advancements but did not fully investigate the sensitivity of the new designs and technology to fatigue or other durability-limiting characteristics. (See pp. 36 and 37.)

Because of the limited technology basis, the contractor found it necessary to apply promising but unproven technology. The contractor defined unproven technology as application of materials, unique mechanical arrangements, or application of technologies from other usage to aircraft engines for the first time. The contractor cited 18 examples of successful applications of unproven technology and 5 examples of unsuccessful applications. Examples were termed successful if the technology was retained in the current F100 engine and unsuccessful if abandoned during the development or production phase.

Application of unproven technology was particularly risky because of schedule constraints. The Air Force initiated development of the F-15 airframe concurrently with its

development of the F100 engine. To provide engines when the F-15 airframes were ready, the Air Force scheduled completion of the F100 qualification tests and start of full-scale production in mid-1973--about 5 years after the award of initial competitive engine development contracts in August 1968 and about 3 years after the award of the full-scale development contract to the winning contractor in February 1970.

The engine development schedule constrained by the concurrent airframe development schedule did not allow time to adequately test the production configured engine before production. For example, F-15 flight tests, including the Initial Operational Test and Evaluation, used early F100 prototype engines, not the later production configured engine. Further, F100 flight testing was directed at aircraft system performance, not engine performance. The F100/F-15 test plans, prepared by the Air Force Flight Test Center, were based upon airframe specifications, not engine specifications. Also, the compressed schedule and lateness in accomplishing a 150-hour durability test of an operationally configured engine reduced the 20 months planned for obtaining flight test experience before the first aircraft deliveries to about 6 months. 1/

According to the Air Force Scientific Advisory Board's 1973 report, new engine developments take twice as long as new airframe developments, and, consequently, normal problems seem to be disastrous when engine developments are compressed to meet airframe developments. The report concluded that fully concurrent engine and airframe developments usually take longer and cost more.

Another factor which may have prevented identifying and resolving many problems, even if more time and money had been available, was the failure to adequately define the engine's missions and usage requirements for design and verification purposes. Engine designers are asked to design engines with a required engine life in hours doing some defined mission. The F100 missions and usage requirements, however, were poorly defined and did not approach the severity of the actual missions. More specifically, contractor officials said that the Air Force did not provide an adequate definition of the F100/F-15 missions, mission mix, and duty

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1/It should be noted, however, that previous engine programs made little or no allowance for flight test experience with operationally configured engines before first delivery to the using command.

cycles (throttle movements) which would totally define the engineering variables required to design the F100 engine.

Also, as required at the time, the F100 engines were subjected to the standard ground test cycles which included (1) a 60-hour preliminary flight rating test (PFRT) and (2) a 150-hour qualification test. These tests were basically endurance-type tests representing steady-state operation at rather severe flight conditions for protracted periods. For the F100 engine, the qualification test plan to run the engine for 30 hours at a speed of Mach 2.3 was particularly severe. The reasoning was that endurance tests demonstrating an engine's ability to operate under such severe conditions would also demonstrate that it had enough margin to operate successfully at less severe steady-state conditions.

The tests, however, were not representative of the engine's anticipated usage and did not adequately demonstrate the impact of thermal/stress low-cycle fatigue on key parts. The combination of many relatively short missions with a large number of extreme throttle variations, which is representative of supersonic fighter aircraft, results in deterioration of parts quite different from those resulting from steady-state operation at severe flight conditions for protracted periods.

Resulting engine problems

The new F-15 fighter experienced a number of engine problems during initial operations and flight tests. The problems involved primarily flight safety, reliability, and durability--areas not fully developed and tested before full-scale production release. The Air Force reported that by April 1979 it had purchased 1,100 F100 engines of a total planned buy of more than 4,000 and had accumulated 250,000 engine flying hours. It also reported that over the past 5 years engine problems have included

--547 stall/stagnations,

--47 failures of turbine blades and vanes,

--60 main fuel pump failures,

--10 afterburner fuel pump bearing failures,

--8 number 4, main shaft bearing failures, and

--reliability of the electronic engine control (150 hours mean time between removal).

The problems have increased inspections, repairs and replacements, and fault isolation actions. The unprogramed workload has resulted in maintenance man-hour backlogs and a higher quantity of engines down for maintenance/supply than anticipated. The downtime adversely affects the F-15 aircraft's wartime capability/operational readiness. To date, an additional $147 million has been provided for replenishment spare parts due to the above problems.

In summary, the Air Force spent $457 million to develop the F100 engine for production and about $383 million in F100 CIPs since production began. The Air Force plans to spend another $283 million on the F100 CIP from 1980-84 in an attempt to achieve the engine's operability and durability goals. By 1984 the Air Force will have spent more than $1.1 billion over a 15-year period to develop acceptable F100 engines for the F-15 and F-16 aircraft. These expenditures do not include costs to procure the engines or costs to incorporate CIP fixes on the engines. Although the latter cannot be determined, the service estimates about $109 million for known improvements to its growing inventory of F100 engines through fiscal year 1981.

F401 ENGINE DEVELOPMENT

In December 1967 the Air Force and Navy agreed to conduct a joint program to develop a high performance turbofan engine for their experimental F-15 and F-14 fighter aircraft. The Navy engine, designated the F401, was to be a larger version of the Air Force F100 engine to accommodate the heavier F-14 aircraft. It was to use a common core gas generator that would be interchangeable with the Air Force's F-15 engine. The Air Force was given management responsibility for the joint F100/F401 development program.

Like the Air Force, the Navy was developing its F-14 airframe concurrently with development of the new F401 engine. The F-14 airframe was ready to be engined for its first flight test in August 1970. The Navy, being contractually liable to furnish engines to the airframe contractor as of that date, began supplying the TF30 engine, which was a modified version of the engine used to power the Air Force's F-111. The Navy originally planned for the TF30 engine to be used as an interim powerplant in the first 33 aircraft, designated the F-14A. It was to be replaced by the F401 engine in the 34th aircraft, designated the F-14B.

According to the abbreviated development schedule, the Navy planned to buy 179 F401 engines from fiscal years 1972-74. In November 1970 the Navy reduced its planned F401 engine buy from 179 to 69 units. In the spring of 1971 the Navy

further pared its order to 58 engines and on June 22, 1971, canceled the remaining 58 engines in accordance with its decision to buy 301 F-14As. In 1973 the Navy suspended the F401 development program because of repeated engine failures during PFRTs and because of funding constraints. The Navy reports that it spent $369 million to develop the F401.

The problems which led to the Navy's decision in 1973 to suspend its development of the F401 engine were the result of attempting to apply unproven technology during a compressed development schedule. Also, the contractor was not given a specific mission for the F-14 until 1972. As stated in the following section on the TF30 engine, the 1972 F-14 mission profile grossly understated the severity of the engines' actual usage.

TF30 ENGINE MODIFICATION

The TF30 engine on the Navy's F-14A is a derivative of the engine on the Air Force's F-111 aircraft. The Navy's modifications to the Air Force's engine included a revised exhaust nozzle, externals and mounts, and an improved burner and turbine. The engine's core and performance characteristics, however, remained basically the same.

The Air Force's development of the TF30 engine for its F-111 aircraft began in October 1961 and was completed in August 1965--a period of 3 years and 10 months. The F-111 engines have experienced stall problems and major deficiencies in reliability and durability.

The Navy's modification effort, resulting in an engine designated the TF30-P-412, took 2 years and 5 months from program initiation to qualification test acceptance, at a then-year cost of $21 million. A brief chronology of the TF30-P-412 engine development follows.

Actions	Date	Elapsed time from program initiation (months)
Program initiated	Jan. 1969	-
Completed PFRT	Aug. 1970	18
Shipped first prototype engines	Aug. 1970	18
First F-14A flight	Dec. 1970	24
Final acceptance	May 1971	29

The engine model specification for the TF30/F-14A engine excluded (1) requirements for reliability, durability, and maintainability and (2) tests designed to determine and verify attainment of these requirements, in spite of operational problems experienced on the F-111. 1/ The engine was approved for production before many durability and reliability problems exhibited during the qualification tests were corrected. We believe these actions demonstrate the point made in the 1976 Procurement Review study which stated that testing, especially reliability and durability-type testing, continues to be the first efforts to go when time and money become short.

Further, the contractor was not given a specific mission upon which to base the engine design modification until February 1972, about 1 year after completing development. The missions were subsequently updated in 1976 and 1977. The 1977 mission profile, which was based on exploitation of the F-14's capability, is 7.5 times more severe than the 1972 mission. As a result, the expected life of certain components sensitive to low-cycle fatigue were substantially reduced. An engine part life assessment was initiated and is currently active for the purpose of defining part lives and establishing redesigns and requirements to meet specific part life goals.

1/In commenting on our draft report, DOD officials said that (1) the original TF30 design was for a bomber aircraft, (2) the original problems on the F-111 were mainly associated with inlet compatibility and were not the kinds of problems found in the F-14, and (3) even if the simulated mission endurance test (SMET) had existed at the time, the TF30 would have had problems due to using a bomber engine in a fighter aircraft.

Our points, however, are: (1) the Navy should have redesigned the engine for fighter applications before final acceptance and production, (2) although different, F-14 inlet/engine compatability has been a problem, and (3) during development, SMET could have pointed up problems to be corrected before production. We believe there was not the time or money to adequately develop the TF30 for fighter applications before production because (1) it was initially only considered an interim engine by the Navy and (2) an early production date was required to meet the airframe production date.

Resulting engine problems

The TF30 CIP began in 1971 upon completion of the engines' qualification tests and approval for production. It has produced the following modifications.

Engine designation change	Description	Cost	Date
TF30-P-412 to 412A	Revised fan section, main fuel control, and afterburner	Production cost increase of $1,385 per engine/$6,000 per engine retrofit	May 1972
P-412A to 414	Improved compressor blade assembly and fan blade containment modifications	Production cost increase of $9,500 per engine/$50,000 per engine retrofit (est. total cost $35 million)	Oct. 1976

The TF30-P-414 still has many problems to be solved before the Navy considers the engine operationally sound. Accordingly, the Navy has initiated the TF30-P-414A improvement program to reduce compressor stalls and improve the low-cycle fatigue and component durability problems. The Navy plans to spend about $75 million from 1979-81 under its CIP to develop and test improvements. It also plans to spend $552 million to install about 33 improvements on about 1,000 engines from 1982-85 or 1986.

In summary, the Navy spent $21 million in 2 years and 5 months to modify an existing engine to power its new F-14 fighter aircraft. From 1971-85, the Navy will have spent about $840 million more in developing and installing engine modifications to correct safety of flight problems and improve reliability, maintainability, and durability of the engine.

In our opinion, the TF30 program demonstrates the point made in the Air Force's Scientific Advisory Board's report of August 1973. The report stated that too many ambitious steps are being taken under the guise of modification programs, particularly in light of the support provided for some of the programs. Although the report cited the J85-21 engine program as an example, we believe it applies to both the Navy TF30 and the Air Force TF34 engine programs. The report

recommended strong management discipline to insure that a thorough assessment of risks is made before commitment to any engine modification program.

TF34 ENGINE MODIFICATION

The TF34 engine for the Air Force's A-10 aircraft is a modified version of a Navy engine which entered fleet service, on the S-3A antisubmarine warfare aircraft, in 1974. Critical design features are the same for both versions, permitting a 90-percent parts commonality. Like the TF30 modification, the TF34 modification did not require an extension of existing technology nor a major increase in operating characteristics.

The Navy began developing the TF34 engine for its S-3A aircraft in 1968, qualified the engine in 1972, and initiated the TF34 CIP in 1972. The Air Force selected the AX-10 experimental aircraft powered by two TF34 engines for its close air support role after the aircraft won competitive flyoffs in July 1972 (against the AX-9) and in April 1974 (against the A-7D). The Air Force awarded a full-scale development contract for the TF34 in August 1972 and approved the modified engine for production in October 1974--a period of 2 years and 3 months.

The Air Force's limited development period did not provide sufficient time to resolve several engine problems that were identified before production. For example, there were problems identified with the stage 1 turbine nozzle, number 3 bearing, "C" sump high temperature O-rings and sump cover, and compressor blade locking nut.

Also, other shortcuts were taken in the development process. The TF34/A-10 engine modification program relied heavily on the Navy's previous TF34/S-3A engine program to fill some of the standard ground and flight testing requirements before qualification approval and start of production. The contractor was only required to test the engines where the Air Force test requirements differed from the Navy program. A PFRT, used to demonstrate that the engine was ready for early flight testing, was not required, and the engine was not flight tested before start of production. Also, because of the A-10 airframe flight test schedule, 20 production engines were delivered to the prime contractor before qualification approval. Although there was an A-10 flight test program after production, the engines were not instrumented to identify flight-caused problems. The flight test program was conducted primarily to test the airframe, not the engines.

The Air Force developed 11 mission profiles that the contractor used to modify the engine to meet performance

specifications. The mission profiles required the TF34 engine to be at maximum power 8 percent of the time. Actual service use, however, shows the engine is operated 18 to 22 percent of the time at maximum power. As a result, the Air Force reduced the design life of the engine's hot section from 1,000 mission hours to 750. Also, the Air Force's failure to identify certain flight maneuvers contributed to its failure to identify the severity of the TF34's number 3 bearing problem.

Although attention was given to improving reliability, maintainability, and durability during the Air Force's TF34 engine modification program, the design life values were goals, not contractual requirements. The engineers were asked to design the parts to satisfy the goals--3,000 useful mission hours for hot section parts and 6,000 hours for cold section parts. The logisticians' plans were based on the goals. The goals, however, were not used in qualification testing. Rather, they are being used in the subsequent CIP to mature the engine to the design-life goals as well as correct service-revealed deficiencies that degrade reliability and durability.

Both the Navy and Air Force discovered a number of serious deficiencies after their TF34 engines became operational. These deficiencies have included "thin wall" and hot salt stress corrosion cracks of fan disks, number 3 bearing failures, "stage 1 bucket" problems, and other durability problems in the combustor and high-pressure turbine. Some problems have been corrected or reduced and others are being investigated during the two services' continuing joint CIP. 1/

In summary, contract costs for developing the Air Force TF34 version were about $14.5 million. Since 1974 the Air Force and the Navy have expended more than $15 million annually on a joint CIP for their versions of the TF34 engine. The two services plan to spend an additional $111 million from fiscal years 1979-83, at a rate of more than $20 million

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1/In commenting on our draft report, DOD stated that (1) the initial TF34 design for an antisubmarine warfare mission was based on estimated throttle transients which were four or five times less than actual because they did not consider the extent of pilots practicing touch and go landings and performing other missions, (2) the Air Force's close air support mission requires even more throttle transients, (3) durability problems have been less severe for the Navy than for the Air Force, and (4) as a lesson learned, an engine must be designed for its most severe application.

per year. The CIP objective is to achieve the engines' durability goals and correct problems discovered during operations. Failure to achieve the TF34/A-10 goals will increase operational and support costs because spare engines and parts, maintenance man-hours, and operational readiness rates are based on achieving the goals.

CONCLUSIONS

Past engine development programs--F100, F401, TF30, and TF34--show the contractors' and the services' tendencies to minimize technical risk and to be overly optimistic in terms of cost and schedule. For the propulsion designers and developers, this is evidence of self-deception. For top-level management within the services and DOD, it is evidence that the facts of life in engine development were not fully understood.

In our opinion, these programs support the following lessons learned on cost and schedule constraints, as reported in Air Force sponsored studies published in 1973 and 1976.

--Developing new or modified engines is an empirical and iterative process that requires much more time and money than previously provided.

--New engine developments, which are only justified as major extensions of technology, have high technical risks that require caution and flexibility in establishing an adequate development schedule.

--New engine developments take much longer than new airframe developments, and the two should not be initiated concurrently if the latter is to be the pacing element.

--Because engines resulting from a modification program may exhibit the difficulties of a new engine and require the long iterative development cycle, a thorough assessment of risks should be made before commitment to any engine modification program. (This also applies to significant risks involved in any decision to relax specified qualification test requirements to maintain schedule targets.)

--Full-scale production decisions should be delayed until the engines have obtained 1 to 2 years of flight testing throughout their expected operational environment.

--Experience indicates that shortcutting engine development, especially reliability and durability-type testing, for the purposes of preventing schedule slips or additional costs poses such potential for costly

problems downstream that it becomes an exercise in false economy.

Also, we believe the above programs demonstrate the need to (1) better define the systems' mission and engine usage for design and testing purposes, (2) give design and testing emphasis to obtaining an appropriate balance between performance, operability, and durability, and (3) not only extend flight testing, but specifically focus some of the flight testing on engine performance and durability.

As discussed in chapter 3, the services' actions to improve their more recent engine programs--F404 and ATE programs--evidence acknowledgement of some of the lessons learned in the earlier programs. However, as discussed in chapters 4 and 5, more corrective actions are necessary to assure that the lessons will not have to be relearned as budget restrictions continue, or become worse, and as the services' memories dim.

CHAPTER 3

IMPROVEMENTS IN CURRENT ENGINE

DEVELOPMENT PROGRAMS

Based on lessons learned in past programs, the Navy and the Air Force are adopting new concepts and procedures for their current engine development programs and CIPs. Major improvements in current programs have been in (1) defining mission and usage requirements for engine structural design and testing, (2) improving engine test methodology, (3) expanding engine flight testing before full-scale production, and (4) emphasizing earlier the engine's reliability, maintainability, and durability. These improvements require substantially more development time and money than provided in past engine development programs.

The discussion of current engine development programs and CIPs in the following sections highlight the above improvements and further demonstrate the need for the other improvements discussed in subsequent chapters.

F404 ENGINE DEVELOPMENT

The Navy reports that its development of the F404 engine for the F/A-18 multimission air combat fighter has been structured to avoid problems encountered with the TF30 and other operational engines. Since the TF30 problems have been in the areas of operability, reliability, maintainability, and durability, the F404 engine program has been expanded to emphasize these areas and to afford them high-level visibility.

Expanded schedule

The F404 engine is a modification of the YJ101 engine which powered the YF-17 prototype lightweight fighter aircraft. The YF-17 competed with the YF-16 in the Air Force's lightweight fighter prototype program which took place between 1972 and 1975. In May 1975 the Navy selected the YF-17 for its air combat fighter and designated it the F/A-18.

Design of the YJ101 engine began in 1970, more than a year before the conceptual design of the YF-17 airframe began. Design and validation of the YF101 engine and full-scale development of the F404 have been conducted over a 9-year period with an additional year of flight testing to be performed before the F/A-18 full-scale production decision.

The delayed start reduced, but did not eliminate, compressed concurrency between the engine and airframe development. The contractor was required to start delivering engines for airframe flight testing before some PFRT design changes could be incorporated. A Navy official noted that because the analysis and design time between PFRT and qualification testing was only 7 months, not all design changes were incorporated in the engines used for qualification testing.

However, by the end of the 10-year development period in August 1980, the F404 engine had completed 14,000 hours of ground testing and about 1,750 flight hours. By the F/A-18 Initial Operational Capability in March 1983, the engine will have an estimated 15,000 hours of ground testing and an estimated 50,000 flight hours. Only 10 percent of the engines will be under contract, with about 7 percent delivered and in inventory by the Initial Operational Capability date.

Improved development testing

Benefiting from lessons learned, the F404 engine's ground and flight testing was based more on anticipated mission usage and requirements than earlier development programs. Besides the PFRT and qualification test, about 1,300 hours of a low cycle fatique test are being run on individual components and the entire engine. The low cycle fatique test is a cyclic endurance test which subjects the engine to at least one lifetime cycling. A cycle consists of an engine start, acceleration to idle, running at idle, acceleration to maximum power, deceleration, and eventual engine shutdown. The contractor was to run 2,000 cycles on the engine's hot parts and 4,000 cycles on the cold parts.

Also, three 750-hour SMETs were run from July 1978 through July 1980. SMET measures the impact of actual mission power usage based on the 9 mission statements provided by the Navy and includes about 79,000 throttle movements. The third SMET ran on one production engine, the first off the assembly line, and will determine the contract award fee for demonstrated reliability.

Although not a contract requirement, the contractor also formulated an accelerated mission test (AMT) plan to more fully evaluate durability. An engine experiences the most fatigue when its throttle is moved and when it is at high power. AMT testing eliminates the nondamaging or insignificant portions of the composite mission profile, such as time at idle or cruising at less than high power. Because of this acceleration factor, the AMT of 1,200 hours is said to be equivalent to about 4,000 hours of SMET. The purpose of AMT is to more rapidly evaluate engine parts affected by thermal cycles and time at maximum power.

The above tests are major steps forward in engine testing since they bring anticipated usage to ground testing and, as such, expose failures which previously went undetected until subjected to field usage. They do not, however, expose many failures brought about by wear or air maneuvers because the complex interactions between interfacing subsystems can seldom be fully anticipated or built into a ground test environment.

Accordingly, the F/A-18 flight test program requires 11 aircraft to fly 4,000 flight hours (8,000 engine hours) from November 18, 1978--the date of the first flight--through early 1982. About 1,500 flight hours will be devoted to engine testing.

Also, 1 of the 11 aircraft will be used for 1,000 flight hours of an accelerated service test. The accelerated service test is primarily directed toward engine testing as opposed to airframe or aircraft testing. The objective is to evaluate engine reliability and maintainability under service conditions. The accelerated service test, which will be equivalent to 4 years of fleet use, began in the last quarter of 1979 and will end in the first quarter of 1982. The contractor estimates that by 1982 less than 4 percent of the production engines will have been produced.

Definition of missions and usage

At the start of the F404 development program, the projected usage was based on 9 missions requiring an estimated 47,485 throttle changes during the engine's projected life of 4,000 flight hours. The Navy subsequently flew the missions in aircraft and on the simulator and found that actual throttle changes were 442,448 per 4,000 flight hours--a ninefold increase. The Navy updated its mission statements and the contractor lowered its hot part life estimates in some cases by as much as 50 percent. The contractor estimated that $35 million would be needed to redesign the parts affected. The Navy decided not to fund this effort and to accept the reduced life of the parts. Subsequent testing indicates that the degradation is only about half as severe as originally anticipated.

Design emphasis on reliability and maintainability

The Navy established the following design priorities, in order of importance, at the start of the F404 development program: (1) operational suitability (ability to perform missions), (2) reliability, (3) maintainability, (4) cost (life cycle costs), (5) performance (thrust, specific fuel consumption), and (6) weight.

An estimated 500 design trade-offs were made during the engine's design and development. However, only about 5 percent of the trade-offs were supported by detailed studies. A contractor official said that trade-offs are primarily based on engineering judgment--experience in engine building, both commercial and military--and life cycle costs as determined from the contractor's operation and support cost model. Further, all design trade-offs were controlled by

--engine specification requirements,

--contractual cost requirements, and

--reliability and maintainability requirements.

Besides establishing the design priorities and contract requirements, the Navy reviewed proposed trade-offs and decided whether or not to accept them.

The Navy also supplied the input data or parameters for the contractor's operation and support cost model from "Navy Factors Manual for F-18 Cycle Cost and Level of Repair Program," dated July 1976. The Navy factors manual is basically designed for purposes of planning and programing, and its cost data will not adequately support detailed engineering trade-off decisions. At best, the contractor's operation and support model can only estimate the gross impact of design decisions on operation and support costs. The model was not used in making trade-offs between elements that the contractor could not translate into costs (for example, performance versus reliability). Decisions of this kind were generally based on engineering judgment.

As shown above, design engineers in most cases do not analyze, or have the capability to analyze, the long-range impact that their decisions will have on an engine's life cycle costs. Engineering judgments without supporting studies do not provide accountability for either the contractor proposing them or the developer agency approving them. Engineering judgments and accountability are further limited by predetermined specification, contract cost, reliability, and maintainability requirements. For true life cycle cost trade-offs, the design engineers need to know the long term cost effects of their decisions and have the flexibility to make logical trades between performance and durability requirements rather than rigidly meeting a series of specific requirements. These and related matters are discussed further under the topic of "Need to Develop Engine Management Policy and Supporting Methodology" in chapter 5, pp. 42 to 45.

Conclusions

The benefit from providing more time and resources to detect, analyze, and correct deficiencies in the engine's operational and supportability characteristics before full-scale production should result in the development of a more mature engine for the operational squadrons. The greater degree of maturity should reduce reliability, durability, maintainability, and stall problems that have plagued the TF30 and F100 engines. However, inadequate definition of mission/usage requirements at the beginning of the engine design process and inability to quantify downstream logistics savings for trade-off studies indicate major areas requiring improvements.

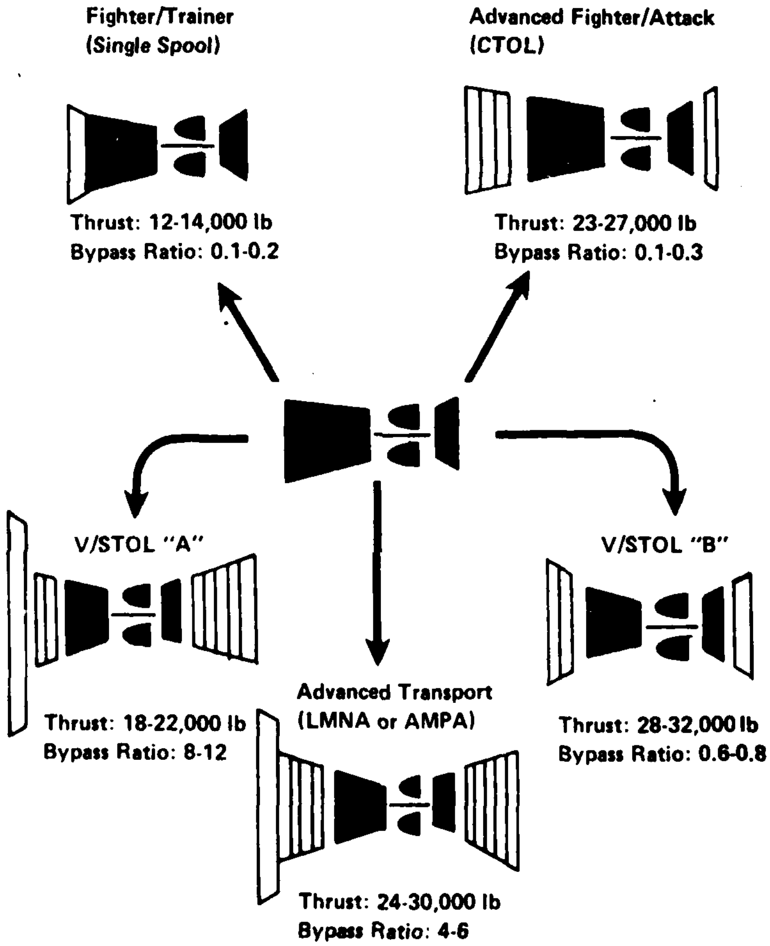
ATE

The Navy and Air Force initiated the joint ATE program in 1979 as a long-range development program for the next generation of fighter engine(s). The new engine's core is to have multiple military applications during the 1990-2000 time frame. (See fig. 2.) With the Navy as the lead service, conceptual design studies are being performed from early 1980 through mid-1981. The Navy reports that the studies are to define requirements; balance requirements among performance, operability, durability, maintainability, and life cycle costs; establish optimum development schedules; and develop strategies for future service engine developments.

Estimated ATE funding from 1980-81 is $8 million. During the same period approximately $126 million is budgeted for ongoing component technology and technology demonstration programs that will provide technology base inputs to the ATE program. Although there is no joint agreement beyond 1981, the Navy estimates development costs, including hard production tooling, to 1990 will total about $1.25 billion. The program's objective is to provide time and resources for an orderly and complete development effort that will avoid the shortcuts taken in past programs which have produced today's engine problems.

The Navy states that it has not specified performance objectives, but rather that its studies are designed to provide an estimate of achievable performance goals balanced with achievable reliability and durability goals. The Navy also estimates that engines for flight test purposes could be delivered no earlier than 1987, engines for low production could be released in 1989, and engines for high production could be released in 1990 or beyond.

NAVY/AIRFORCE MULTIPLE APPLICATION CORE



While the Navy has not specified performance objectives, DOD officials have indicated goals of about 10 to 1 for thrust-to-weight with a possible 30-percent reduction in life cycle costs. Although these goals are only projections, the next generation engine that will cost $1.2 billion in development and be used for fighter applications in the 1990s will have to be justified based on major improvements in performance. As noted previously, ambitious performance goals will require major extensions of technology with high technical risks that will require caution and flexibility in establishing an adequate development schedule. For these reasons, the ATE program could be a good test to show how well the lessons of the past have been learned and are being applied.

F101 DERIVATIVE FIGHTER ENGINE PROGRAM

Pursuant to congressional direction, the Air Force and the Navy initiated the F101 Derivative Fighter Engine (DFE) program in 1979 to develop an alternate engine for the Navy's F-14 and the Air Force's F-16 aircraft should the TF30 and F100 CIPs fail to correct existing safety of flight difficulties (compressor stall problems) and show positive trends in improving supportability and reducing costs of ownership.

Both services expect their F100 and TF30 CIPs to show by 1981 that they can correct existing engine deficiencies, at which time the F101DFE program would be terminated. However, if the CIPs do not demonstrate satisfactory fixes, a decision to continue into full-scale development could be made depending on the services' assessment of the F101DFE test results.

As presently structured, the F101DFE program, like past programs, will initiate engine production before completing its development. The 30-month, $93 million limited development and demonstration effort is to design, fabricate, assemble, and test three development engines by 1981. The testing consists of durability and flight clearance tests that will culminate in about 200 engine hours of flight tests in F-14 and F-16 aircraft. The purpose of this limited effort is to demonstrate the F101DFE's ability to overcome existing engines' problems and its potential for use on both aircraft.

If approved, the follow-on 27-month, $455 million full-scale engineering development effort is to fabricate and assemble 9 more engines and subject all 12 engines to the more extensive tests, including flight tests, that are required to qualify the engine for production. However, initial production of 56 engines is to be undertaken concurrently with full-scale development to provide engines for the Air Force's proposed follow-on buy of F-16 aircraft.

The F101DFE program as structured for the early production of Air Force engines constitutes "planning for success" which creates its own risks. Any engine problem that is identified during limited development testing or qualification testing and is not easily corrected threatens the production schedule and the program. The alternative would be to continue with the production schedule and correct the problems during CIPs, which is the approach used in past programs.

The Navy, on the other hand, should it decide to support the program beyond 1981, plans to complete full-scale development 1 year later than the Air Force and plans no production before completion of the engine's development. Since F-14 production will be completed by that time, the Navy's 1981 decision will be more dependent on the issue of affordability than the engine's characteristics. That is, can the Navy afford the $3 billion to $4 billion required to substitute the F101DFEs for its TF30 engines beginning in 1985?

CIPs

In addition to improving current engine development programs, the services and their contractors are adapting SMET, AMT, and Lead-the-Force (LTF) concepts and methodologies to their CIPs on the F100, TF30, and TF34 engines as discussed below. For example, the Air Force engines that have been subjected to AMT as part of their continuing CIPs are listed below:

Accelerated Mission Test Status
as of January 31, 1979

Weapon system	Engine	Equivalent mission hours	Acceleration factor (equivalent operating time by test time)
F-15/F-16	F100	7,830	F-15 = 3.1, F-16 = 2.9
A-10	TF34	22,792	2.0
F-111	TF30	7,449	2.3
A-7	TF41	8,394	2.0

Also, the Air Force has instituted LTF programs for its F100 and TF34 engines. The Air Force's LTF concept requires that a representative sample of operational engines in the inventory be used to identify deficiencies before they affect the operational capability of the balance of the engine inventory. This is done by accelerating the use of selected engines taken from different production blocks entering the operational inventory. Air Force regulations require the LTF engines to have a utilization goal of two to one over the force average.

During fiscal year 1979 hearings before the House Armed Services Committee, an Air Force official testified that with the LTF program the F100 engine is "* * * ahead of practically every other engine I can recall at this point in time on durability testing." Although this may be the case, the F100 is failing to meet its required utilization goal of two to one over the force average. The target fly rate for the F100 in F-15 aircraft is 54 hours total operating time per month, whereas the force average is 20 hours per month. When the LTF engines are flying they achieve about 50 hours per month, but when downtime and inspections are included the average comes down to about 25 hours per month. The impact of this, we were told, is little reaction time between finding problems on the LTF engines and their appearance on other engines in the force.

The Air Force has a total of 6 A-10 aircraft (12 engines) in its TF34 engine LTF program.

The Navy does not have an LTF program comparable to the Air Force. Instead, the Navy performs trend analyses on engines inducted into the depot for repair and rework, which are then correlated with the results of accelerated simulated mission endurance tests (ASMETs) which are similar to AMTs. The Navy states that this approach allows time to develop corrective actions, since the high time TF30 fleet engine has reached about 1,400 hours and the high time ASMET engine has reached 4,200 equivalent mission hours.

For example, contractor representatives said that the Navy's TF30 ASMET has found a number of problems not seen to date on fleet engines. These problems apparently are similar to those experienced in 1978 by the TF30 engines on the Air Force's F-111 aircraft. The Air Force Chief of Staff said in hearings before the House Appropriations Defense Subcommittee that the TF30s in the F-14s have not yet accumulated the flying time of the F-111s, but the F-14s may begin to have the same kind of low cycle fatigue problems starting soon, requiring change-out and fixes.

The ASMET, AMT, and LTF concepts, if fully implemented, should reduce the time required to identify and resolve operational problems required to mature the engine. Over the past 10 years, the time to mature fighter engines appears to have increased significantly. Instead of 3 to 4 years and about 200,000 flying hours, DOD officials now talk in terms of 6 to 8 years and 1 million flying hours. Although maturity may be defined differently for purposes of measuring the time to reach it, we note that the Air Force and its contractor do not expect to demonstrate that their F100 CIP objectives have been achieved before 1983, about 10 years after production began

and after the engine has accumulated about 2 million flying hours. Such a delayed maturity increases spare parts and maintenance costs; reduces operational readiness for the extended period; and increases CIP and engine retrofit costs, as reported in chapter 2.

Because of the delayed maturities and the enormous sums being spent on CIPs and on incorporating the resulting engineering changes to the F100 and TF30 engines, the Congress and others have expressed growing concern over the purpose, effectiveness, and control of CIPs. To improve its control over CIPs, the Air Force proposed establishing a historical data bank for engineering changes and proposals that would assist engine project managers in correlating proposed changes with actual experience on similar changes to other engines.

In 1976 the Propulsion System Project Office initiated actions to establish the data bank. Data on engineering changes were to be stored in a computer along with a history of how well they worked and to what extent specific problems were solved. Such information was expected to preclude the need for "reinventing the wheel" and the so called "fix on fix" approach to problem solving. In general, the data bank is to aid in controlling the engineering effort and provide a financial record of its cost effectiveness.

Because of problems encountered during 1977, the Air Force's Propulsion System Project Office, in 1978, directed its limited resources to establishing a data bank on engine deficiencies and their proposed cures for the F100 engine program. During 1979, the Office continued to refine and expand the system set up in 1978 and to examine other storage techniques. The primary objective of permitting future engine operating data to be correlated with the data bank to measure success of prior engineering changes and provide closed loop accounting of the effectiveness of engineering changes is yet to be realized.

CONCLUSIONS

Better structured and more complete engine development programs, as evidenced in the F404 program and promised in the joint ATE program, should result in fewer and less severe problems being surfaced during operations than in past programs reported on in chapter 2.

Because actual service environments cannot be fully anticipated or realistically duplicated during development testing, a number of problems will, by necessity, be identified and resolved after the engines enter service. Also, there are other problems that are only statistically visible and

which can only be discovered as large numbers of production engines accumulate flight experience. Consequently, the new programs will still require critical CIP activity during their production and early deployment phases.

Further CIP activity, although phased down, usually continues as long as the engines remain in the active inventory. Operational and maintenance environments change over time, and new hardware, production, and maintenance techniques are developed to lower the engines' life cycle costs. The continuing CIP provides the necessary engineering support for an aircraft gas turbine engine to maintain a desired operational capability over time, while reducing its manufacturing and operational support costs whenever possible.

In our opinion, the issue is not the need for CIPs, but rather the need to first ensure engines are more fully developed before they are released to full-scale production rates and second to identify usage problems in the actual operational and field maintenance environments as early as possible. More complete development would enable more problems to be identified and resolved during development when corrective options are greater and costs less, and earlier identification of operational problems through AMT, ASMET, and LTF programs would shorten the maturity phase following production producing further savings and operational benefits. Such a disciplined approach, however, requires the corrective actions discussed in chapters 4 and 5.

CHAPTER 4

CURRENT STATUS OF

NEW ENGINE DEVELOPMENT

CONCEPTS

As evidenced by their actions to improve existing programs, the Air Force and the Navy are defining new management approaches that will more fully develop aircraft gas turbine engines before full-scale production. The Air Force's efforts have led to organizational changes and its "New Concept for Engine Development." The latter stresses a more complete and disciplined approach to engine design, development, and operational testing.

AIR FORCE ORGANIZATIONAL CHANGES

The Air Force established the Propulsion System Project Office to function as the single engine manager within the service. Before 1976 the aircraft engine was treated as just another subsystem on a weapon system. There was no single organization responsible and accountable for engine management within the developing command. The Air Force also established the Acquisition Logistics Division within its developing command to make operational and maintenance requirements an integral part of engine development.

AIR FORCE CONCEPTUAL CHANGES

The Air Force's new concept for engine development was initiated largely on the basis of findings, conclusions, and recommendations in the 1973 report of its Scientific Advisory Board Ad Hoc Committee on Engine Development. The new concept lengthens an engine's development program from 4.5 to 6 years to 9 to 15 years and time phases engine development to coincide with its airframe development cycle. Incorporation of structural integrity into the development process is of critical importance.

Engine structural integrity program

The Air Force plan to incorporate structural integrity into the development process is embodied in the Engine Structural Integrity Program (ENSIP). ENSIP emphasizes including structural integrity requirements for designing and testing the engines during development and for maturing the engines during the initial operational phase. The testing

is to be achieved through AMT and LTF programs discussed in chapter 3.

ENSIP's evolution began in 1969 as a structural program written for the B-1 bomber engine (later called the F101). ENSIP has grown and evolved on a lessons learned basis from the many engine programs that experienced structural problems. Parts of ENSIP have been used to some degree on several engines.

The Propulsion System Project Office reported that ENSIP's scope, policy, and philosophy had been established and an overview presented in a 1978 technical paper. In May 1980 the Office reported that a first draft of the formal specification document incorporating ENSIP had been prepared and was being reviewed for possible approval late in calendar year 1980. It reported that full implementation of the ENSIP program to new weapon systems is envisioned.

Comparison of current and planned development practices

The chart below summarizes and points out the differences between planned development practices under the new concept for engine development and current practices. It is part of a briefing titled "Improving the Technical Development and Business Management Practices for Gas Turbine Engines" presented to the Commander of the Air Force Systems Command in March 1978.

Comparison of the Current and Planned Approach in an Engine Conceptual Validation and Full-Scale Development Phase

Current approach	Planned approach
Conceptual phase:	
Limited funding to support engine-airframe performance trades	Develop engine life cycle cost model(s) Conduct performance/cost trade sensitivity studies to identify high technical/cost risks Identify content of validation phase program for least life cycle cost
Demonstration and validation phase:	
Design demonstrator for performance	Design engine with ultimate system requirements in mind
Limited usage of performance rigs	Complete complement of full-scale performance/structural rigs
Limited mechanical design analysis	Comprehensive preliminary design analysis
Demonstrate engine performance and stability potential	Conduct balanced engine test effort Validate life cycle cost model/analysis/trades Identify content of full-scale development program Complete full-scale development redesign for long lead hardware
Full-scale engineering development phase:	
Experimental production and mature engine requirements/goals	Production only requirements
Nonmission usage related endurance test	Mission usage related endurance test
Limited aeromechanical test	Full flight envelope aeromechanical demonstration
Arbitrary time between overhaul/max. operating time	Demonstrated time between overhaul/max. operating time
No life limits demonstrated	Demonstrated life limits
Limited logistics demonstrated	Comprehensive logistics demonstrated
Limited scope flight evaluation	Comprehensive/timely flight evaluation
Limited evaluation of production engines	Max. use of production engines in full-scale development testing
Limited life analysis	Complete life analysis
Limited acquisition cost trades	Validate life cycle cost model

The Air Force regulation incorporating the new acquisition philosophies had been in process for over 4 years. On April 14, 1980, Air Force Regulation 800-30 was published describing life cycle management of aeronautical gas turbine engines. The regulation provides guidance for coordinating the actions of the developing, using, and supporting commands and outlines actions needed during preacquisition efforts to develop the technology base and during all phases of the acquisition cycle. The latter includes not only conceptual, demonstration and validation, and full-scale engineering development phases, but also the production and deployment phases.

Regarding ENSIP and Air Force Regulation 800-30, Air Force officials said the lessons of the past have been learned and all appropriate corrective actions are being taken to the extent permitted by manpower and funding constraints.

Our review of the recently initiated F101DFE program indicates that the qualification--to the extent permitted by manpower and funding constraints--may be substantial. More specifically, the F101DFE program has funding and schedule constraints that may prevent attaining acceptable reliability, maintainability, and durability characteristics should a decision be made to go into full-scale engineering development concurrently with initial engine production in 1982 and full-scale production in 1983-84. The early production dates are based on obtaining an alternate engine for the follow-on buy of F-16 aircraft.

NAVY ACQUISITION CHANGES

Navy representatives said that their propulsion community is a small close-knit group of engineers with good vertical and horizontal communications and that the lessons learned and future actions needed are known and obvious to all concerned. The application of lessons learned is done on each new Navy engine program by senior personnel who give attention to past and current experiences with engines in operational service and decide what can and should be done better.

The representatives said that the most noticeable examples of applied lessons learned are (1) the Navy specifications of detailed throttle excursions in the mission profile definitions, (2) the attention to turbine inlet temperatures as opposed to downstream tailpipe temperatures, (3) the requirement for detailed "failure mode and effect criticality analyses" early in the program, and (4) the addition of

ASMET in a test cell and an accelerated service test in an airplane.

Navy representatives also said that they have started compiling a "rationale file" on the reasons behind current and future requirements. This is intended to document much of the "corporate memory" of senior personnel. Specifically included are lessons learned and the recommended ways to do better on future programs.

During 1980 Navy representatives planned to put the service's development philosophy into a formal document. Currently, a draft document is being reviewed and is expected to be approved in late 1980. They also plan recommended revisions to military engine specification documents for those portions that fit specifications criteria.

CONCLUSIONS

New and derivative engine programs are subject to the ever present prospect of severe budget restrictions coupled with pressing operational needs for early system deployments. Consequently, the incorporation of the Air Force's new approach to engine development in Air Force Regulation 800-30 should provide some continuity and guidance as memories dim, budgeting restrictions continue or become worse, and as pressures to reduce acquisition time and costs increase. However, as discussed in chapter 5, the actions needed to develop the supporting methodology, data base, and analytical procedures have either not been taken or are incomplete.

The Navy's new approach to engine development, which also requires more development time and money, is equally vulnerable to those pressures that push new and modified engines into production before they are ready. The Navy is still formalizing its development philosophy. Like the Air Force, the Navy will need to develop the supporting methodology data base and analytical procedures to support future engine developments, as discussed in chapter 5.

CHAPTER 5

OTHER SUPPORTIVE ACTIONS NEEDED

Supportive actions are needed to fully implement and justify the Air Force's and the Navy's new approaches to engine development. That is, advocates of the new approaches must be able to

--quantify the benefits to be derived by the additional testing and the lengthening of the engine development process and

--minimize the increased development time and costs by making the long empirical, iterative design process as rational and analytical as possible.

To achieve these ends, the service developers must bring promising new technology up to the point that it is ready for system application; develop an engine management policy that defines development objectives on the basis of performance, operational readiness, and life cycle costs; develop the data base and analytical procedures to support the management policy; and improve contractor incentives by enabling logistical considerations to be stated in contractual terms.

A modern fighter gas turbine engine may consist of 20,000 to 30,000 parts or more. All are interrelated, and a change in one usually affects many others. These parts are exposed to a wide range of stresses, temperatures, and wearing conditions. Propulsion spokesmen said that no single engine characteristic or operating variable poses a major problem if taken individually. However, when the engine must be capable of handling all conditions almost simultaneously, the number and complexity of the interrelationships involved are beyond the capacity of the most advanced computers and well beyond human capability. Accordingly, fighter engine development has been, is, and will continue to be, in part at least, an empirical and iterative process that requires engines to be built, tested, failed, fixed, rebuilt, and so on until an acceptable engine emerges.

This long process, however, can be reduced and made more rational or analytical by (1) expanding technology demonstrator programs to more fully evaluate new technology before it is incorporated into an engine development program, (2) developing

a standard measure for defining the "goodness" 1/ of an engine based on its performance, operational readiness, and life cycle costs, and (3) establishing the data base and analytical procedures for realistic risk assessments, design-to-cost studies, reliability and maintainability assessments, and for true life cycle cost trade-off decisions. The latter are needed to support the goodness criteria and to specify the criteria in contractual terms.

NEED TO EXPAND TECHNOLOGY DEMONSTRATOR PROGRAMS

New engines are dependent on the availability of enough new technology to justify their development. Ideally, when a system enters the full-scale development phase, all technology in the engine should be fully proven or entail only minor advancements with low risks. According to this objective, the services fund advanced development programs to bridge the gap between new concepts and their introduction into real engine programs. The Advanced Turbine Engine Gas Generator (ATEGG) and Aircraft Propulsion Subsystem Integration (APSI) programs are two major advanced development programs 2/ whose objective is to insure engine technology grows and is available to meet the propulsion requirements for future aircraft.

Every major engine since the mid-1960s had its beginning in the ATEGG-type program. Most of the technical advancements in the TF39, F100, and F101 engines came directly from the ATEGG program. The ATEGG/APSI programs will also provide technology for the recently initiated ATE program.

The Air Force Aero Propulsion Laboratory maintains the ATEGG/APSI programs on a continuing basis at four engine contractor plants--General Electric, Pratt & Whitney, Detroit Diesel Allison, and Teledyne Continental. The ATEGG program incorporates new component technology for the gas generator

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1/Term used in the 1976 DOD Procurement Management Review of the Air Force's aircraft gas turbine engine acquisition and support activities. (See app. I.)

2/Other programs are the Navy's Advance Aircraft Propulsion System/Joint Technology Demonstrator Engine, and Propulsion Component Technology. Our review was limited to management actions taken to correct deficiencies previously identified in the two Air Force programs which have contributed to many recent engine problems.

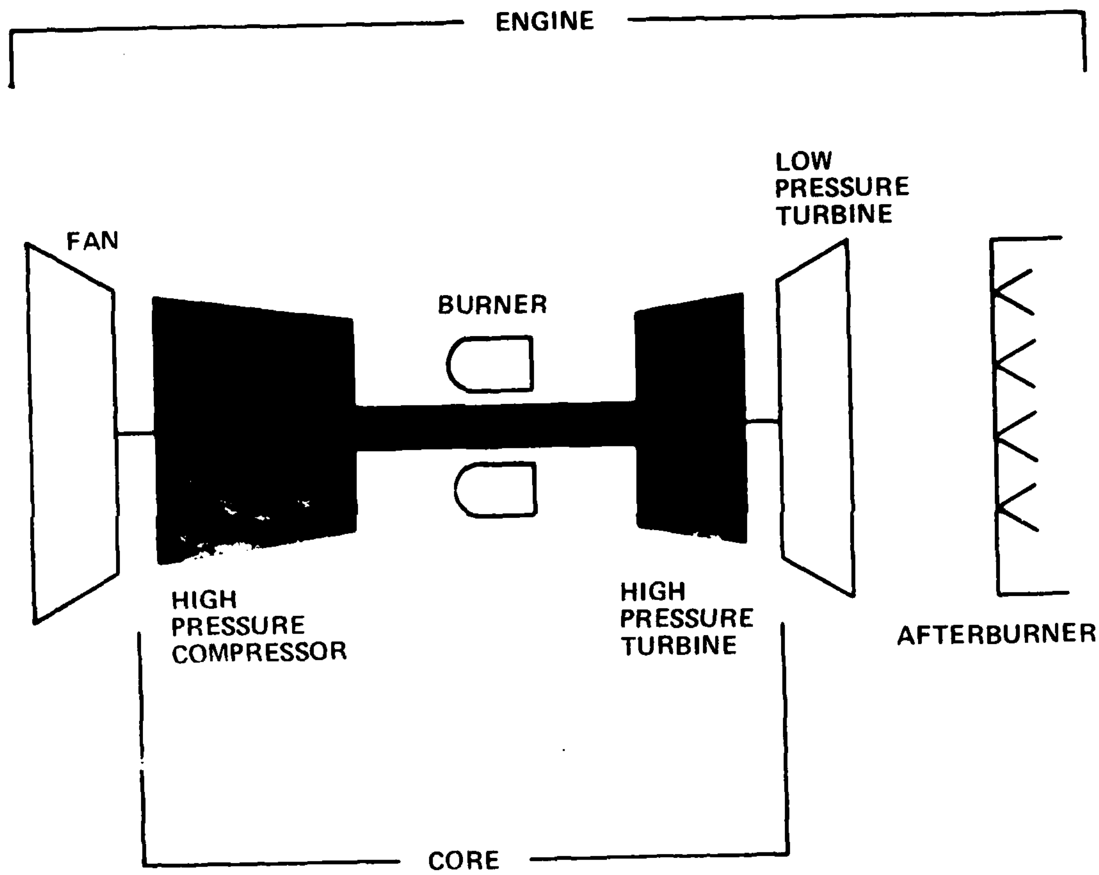
which is the "heart" or core of a turbine engine and includes the high-pressure compressor, combuster, and high-pressure turbine. The gas generator core encompasses the components that operate under the highest pressures, temperatures, and stresses. As a result, the gas generator determines not only the internal performance but the major life reliability and cost characteristics of the turbine engine. The APSI program develops all the other engine components--inlets, fans, low-pressure turbine, augmentor controls, and exhaust nozzles--and integrates them with the ATEGG's compressor, combustor, and turbine into a working engine. (See figs. 3 and 4.)

Since 1973, several Air Force-sponsored studies have criticized the ATEGG/APSI programs for not doing more to fully develop technology and, in particular, to improve durability rather than merely concentrating on performance. In August 1973 and January 1976 the Air Force's Scientific Advisory Board reported that funding for engine research, development, test, and evaluation was too low to minimize engine life cycle costs because there was insufficient effort on structural technology. There is little point, the 1976 report stated, in demonstrating improved performance of a compressor in the ATEGG/APSI programs if it is so sensitive to fatigue that it cannot be reliably used in an engine. If durability problems are not discovered and corrected during ATEGG/APSI, they will become apparent during full-scale development or after the engine is operational when corrective options are less and costs much greater.

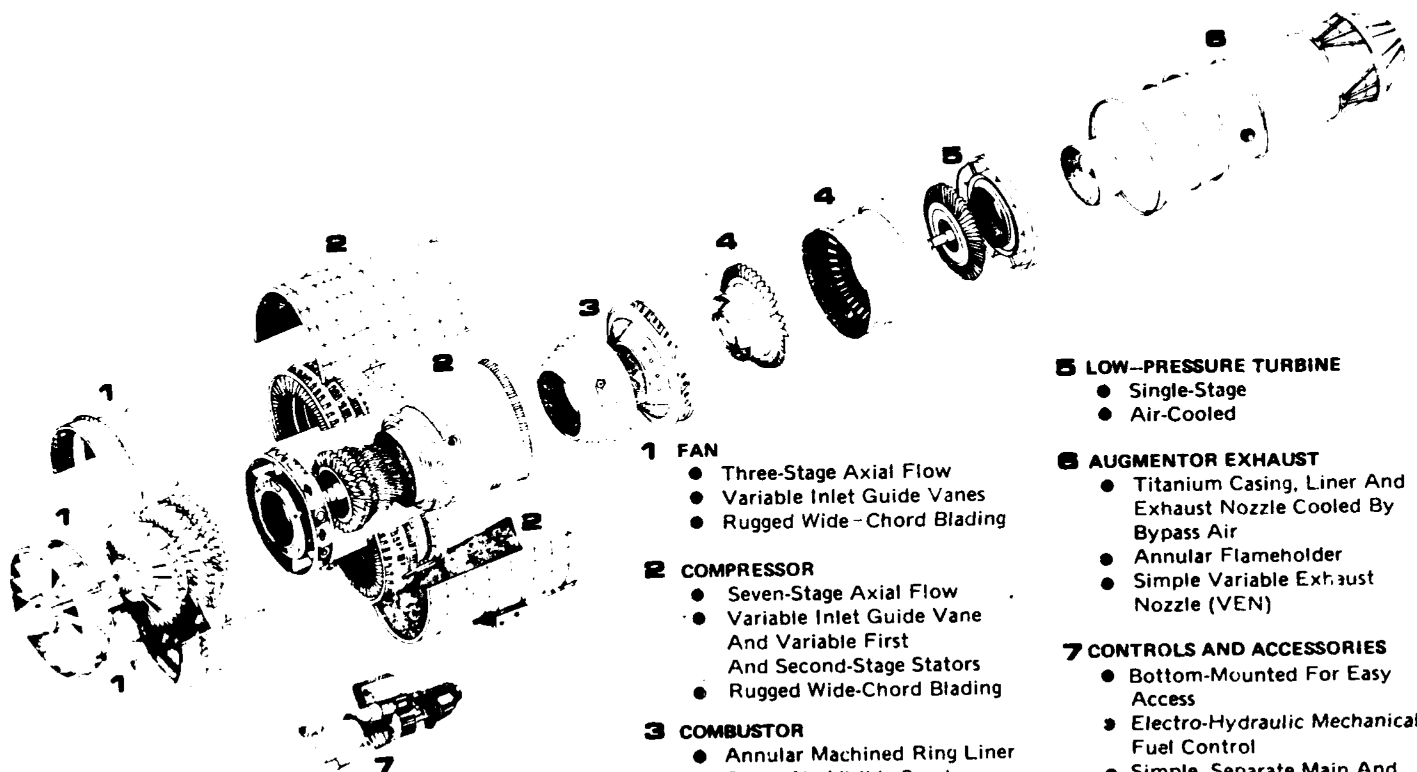
The 1976 DOD Procurement Management Review report stated that since it has been impossible to obtain enough money to bring technology up to the point that it is fully ready for system application, technology has been developed and proven during full-scale development programs. The report notes that this approach increases the technical risks and usually assures cost, schedule, and performance problems. As discussed in chapter 2, these problems, in turn, constrain the full-scale development efforts and usually result in inadequate reliability and durability-type testing during development.

Another key point made in the DOD Procurement Management Review team's report is that most technology advancements can be used to improve performance or increase life (durability). The report states that rarely can both be done simultaneously on a given engine unless a compromise is accepted. In our opinion, insufficient emphasis on structural technology during ATEGG/APSI not only makes such compromises unlikely, but unknown before the design of new engines.

DEFINITION OF ENGINE AND CORE COMPONENTS



NAVY/GENERAL ELECTRIC F404 AUGMENTED TURBOFAN ENGINE



1 FAN
- Three-Stage Axial Flow
- Variable Inlet Guide Vanes
- Rugged Wide-Chord Blading

2 COMPRESSOR
- Seven-Stage Axial Flow
- Variable Inlet Guide Vane And Variable First And Second-Stage Stators
- Rugged Wide-Chord Blading

3 COMBUSTOR
- Annular Machined Ring Liner
- Clean, No Visible Smoke

4 HIGH-PRESSURE TURBINE
- Single-Stage
- Air-Cooled

5 LOW-PRESSURE TURBINE
- Single-Stage
- Air-Cooled

6 AUGMENTOR EXHAUST
- Titanium Casing, Liner And Exhaust Nozzle Cooled By Bypass Air
- Annular Flameholder
- Simple Variable Exhaust Nozzle (VEN)

7 CONTROLS AND ACCESSORIES
- Bottom-Mounted For Easy Access
- Electro-Hydraulic Mechanical Fuel Control
- Simple, Separate Main And Afterburner Fuel Control
- Full Autrority Electronic Afterburner Variable Exhaust Nozzle Control

Because of the earlier Scientific Advisory Board report, the Air Force Aero Propulsion Laboratory made plans to increase funding to permit two core engine test vehicles per contractor for the ATEGG/APSI programs so that an adequate assessment of stability, hot section life, distortion sensitivity, and other structural evaluations could be made.

The money originally requested to support the increased scope of the ATEGG/APSI program was subsequently reduced by the Air Force, as shown in the following schedule.

Comparsion of Funds Requested for ATEGG/APSI Structural Testing to Funds Budgeted

	FY 1978	FY 1979	FY 1980	FY 1981	FY 1982	FY 1983	FY 1984
	(millions)						
ATEGG:							
Requested	$16.4	$23.0	$25.0	$28.0	$30.0	$32.0	$34.0
Budgeted	16.4	18.0	20.0	25.0	27.0	28.0	30.0
Shortage	0	5.0	5.0	3.0	3.0	4.0	4.0
APSI:							
Requested	10.0	16.0	20.6	26.0	28.0	30.0	32.0
Budgeted	10.0	13.2	14.0	14.2	20.1	22.4	26.1
Shortage	$ 0	$ 2.8	$ 6.6	$11.8	$ 7.9	$ 7.6	$ 5.9

Because of cutbacks in ATEGG funding, performance and structural testing were delayed at three contractor plants. At the other plant, plans to add a second core engine test vehicle were also delayed. Funding limitations in the APSI program preclude a second core engine test vehicle dedicated to structural testing at each contractor facility.

In testimony before the Senate Armed Services Committee as late as April 1979, a DOD official said that the Air Force ATEGG/APSI programs are the heart of advanced turbine engine technology. Despite this recognized importance, the Air Force's 1980 budget submission of $20 million for ATEGG and $14 million for APSI did not request the funding needed to eliminate the above shortages.

However, in its September 1979 report on DOD's Appropriation Bill for 1980, the House Committee on Appropriations recommended additional funding of $25 million in fiscal year 1980 Navy and Air Force research and development budgets to begin durability testing of advanced engine components and

technology demonstrator engines. The committee recommended that the $25 million be distributed as follows: (1) $10 million for ATEGG, (2) $5 million for the APSI/Joint Technology Demonstrator Engine, (3) $5 million for the Advance Aircraft Propulsion System/Joint Technology Demonstrator Engine, and (4) $5 million for the Advance Aircraft Propulsion System/ Propulsion Component Technology. The committee explained its actions by stating:

> "As presently structured, these programs provide for a minimum amount of hardware for performance tests only. The proposed $25,000,000 increase would be used to fabricate additional sets of R&D [research and development] hardware for use in the more strenuous durability tests in which these components and engines are apt to be worn out or destroyed."

The Senate Committee on Appropriations recommended concurrence in the House action, and moneys were appropriated.

If adequately supported, durability testing of advanced engine components and technology demonstrator engines will improve the technology base for new engine programs and thereby reduce development failures, costs, and schedules. More specifically, the expanded technology base provides for more realistic risk assessments, design-to-cost studies, reliability and maintainability assessments, and life cycle cost trade-off decisions during the early design phases.

We believe, however, the qualification, if adequately supported, must be made since these technology base programs have consistently been given a lower priority than other engine development programs during the Air Force's budget formulation process. Despite its recognition of the need for the structural testing in the ATEGG/APSI programs since 1973, the Air Force has failed to adequately fund the programs for structural testing for the past 7 years.

Air Force Regulation 800-30 outlines actions that include structural testing of technology demonstrator engines. The Air Force's budget requests for fiscal year 1981, however, show a $5,500,000 reduction for APSI and a $4,300,000 reduction for ATEGG when compared with the level of funding provided during fiscal year 1980. The amounts requested for fiscal year 1981 are $13.5 million for APSI and $25.7 million for ATEGG. These amounts are less than those originally requested to support the increased scope of the ATEGG/APSI program, as shown on p. 40, and may not sustain the 1980 congressional initiative.

NEED TO DEVELOP ENGINE MANAGEMENT POLICY AND SUPPORTING METHODOLOGY

The services' emphasis on performance during engine development has contributed to the lack of standards, data base, and analytical procedures to identify an appropriate balance among performance, operability, reliability, durability, and life cycle costs. Although new emphasis is on improving durability, there is still no engine management policy nor the supporting data base and analytical procedures to implement such a policy during an engine's early design and development phases.

The case for an engine management policy and supporting methodology was made in the 1976 DOD Procurement Management Review of the Air Force's aircraft gas turbine engine acquisition and support activities. The review team's report stated that there was no common criteria for measuring the goodness of an engine. Consequently, developers measure goodness based on whether contractual requirements have been adequately demonstrated within the time and cost constraints, users by whether the engine's performance and operational readiness satisfy mission requirements, and the support planners by whether the engine is sufficiently stable to adequately plan and provide for its logistical support. The engines' life cycle costs or relative cost effectiveness are generally unknown and do not enter the evaluation process.

The report noted that technology justifying new engine programs can be used either to meet major extensions in performance requirements or to improve reliability and durability. The report stated that rarely can both objectives be achieved simultaneously. For example, close tolerances yield more thrust and better fuel consumption, but they also cause higher production and maintenance costs.

Durability and maintainability usually imply added weight which reduces performance capabilities. Because systems are normally plagued by weight growth and, consequently, performance attainment problems during full-scale development, logistics support improvements that add weight have usually run a poor second in design trade-offs between performance and durability.

The 1976 report stated that the study team was unable to find one major decision made in favor of reliability, maintainability, or durability over performance or schedule based on a resulting cost savings. The report concluded that logistic considerations will not determine the choice of technology or be given equal weight in trade-off decisions until (1) a

believable life cycle cost model is developed which demonstrates the impact of engine logistic costs on total system costs and (2) those responsible for new system developments are forced to defend total costs rather than only system acquisition costs. The report also stated that until the Air Force improves its life cycle cost data collection system on existing systems, it will be difficult to verify any life cycle cost model.

Our review of the services' more recent engine programs shows that design decisions have been made in favor of maintainability, durability, and costs over performance without life cycle cost models to demonstrate the impact on total system costs. For example, key design decisions were made in the Navy's F404 program that traded off some performance for production cost savings, reduced component complexity, and weight reduction--single versus dual stage low-pressure turbine, and three stage versus four stage fan. Also, a chem-milled titanium structure was selected over the lighter weight honey combed sandwich structure for the F404 engine's outer ducts. The contractor claims significant cost savings will be realized in terms of acquisition and spare parts costs.

The Air Force's modification of the F101 engine for its F-16 applications stresses reliability and durability over performance. Also, the Air Force plans to derate the engine if it goes into production and further improve its durability at the expense of some performance.

The objective of management's emphasis on durability over performance in both programs is to avoid the durability problems being experienced with the TF30 and F100 engines. The new emphasis is the opposite of the previous emphasis on performance over durability. The new emphasis like the old emphasis does not seem appropriate for new engine programs that will be justified based on state-of-the-art advancements in both performance and durability, such as the ATE program. In the latter program, the objective is to strike an appropriate balance between performance, operational readiness, and life cycle costs. This requires a concept of what the balance should be and developing the means to measure it.

In 1976 the Air Force Aeronautical Systems Division stated that it would (1) complete an engine life cycle cost model to identify cost drivers for use in source selections in December 1976, (2) expand ground testing in fiscal year 1978 until the planned ability to perform and integrate various trade-off and sensitivity studies is reached, and (3) continue to pursue techniques to accomplish trade-off and sensitivity studies.

In 1979 the Propulsion System Project Office of the Air Force Aeronautical Systems Division reported the following progress.

--The joint Air Force/industry engine life cycle cost model was completed short of programing for computer usage as of December 1976. Due to manpower constraints, the cost model still remains unprogramed.

--Ground testing was expanded in fiscal year 1978, and the Propulsion System Project Office is continuing to seek ways to improve trade-off and sensitivity analysis techniques.

--The Propulsion Office was validating a design sensitive operating and support cost simulation model in conjunction with the Air Force's Aeronautical Propulsion Laboratory for use in trade studies.

Until an engine life cycle cost accounting-type data base is established, however, we question whether any operating and support cost simulation model can be adequately validated to support true life cycle cost trade-offs.

Also, the life cycle costs data base and model must be relatable to the engines' missions and usage because of the direct correlation between an engine's costs and its usage. Our review of fighter engine programs shows that initial mission and usage requirements have understated the severity of the requirements by factors of three, seven, and even nine.

Although little progress has been made in establishing an engine life cycle cost accounting-type data base, new sophisticated analytical design tools are being used today that were not available as little as 5 years ago. Air Force representatives cite examples of their use of holography, computerized three-dimensional finite element analysis, and photoelastic analysis to improve understanding of component working stresses and stress fields early in the design process. These tools permit a more rational and analytical approach to designing in durability during engine development.

Air Force Regulation 800-30 outlines actions for the developing, using, and supporting commands to provide the most favorable life cycle engine costs that will meet their sometimes conflicting requirements for the system. Together they are to formulate a program plan for a workable life cycle cost model and, by the end of the conceptual phase, to have jointly developed a definitive mission element need statement.

The mission element need statement is to outline specific mission usage profiles and quantitative objectives for the engine's performance, maintenance concept, durability, and desired operability characteristics (that is, so called "measures of merit," such as unscheduled engine removal).

In subsequent development phases, the contractor is to validate or update the life cycle cost model trade-offs, and sensitivity studies and demonstrate achievement of engine objectives. The developing command is to conduct an ENSIP during development, and the using command is to identify or validate mission usage profiles before full-scale engineering development and provide changes to the approved profiles throughout the useful life of the engine.

With the issuance of Air Force Regulation 800-30, the issue is no longer what should be done but how will it be done. Collectively, an engine management standard, a life cycle cost data base, a closed loop accounting system for engineering changes, and the analytical capabilities for realistic reliability and maintainability assessments and true life cycle cost trade-off decisions are needed not only to implement Air Force Regulation 800-30, but also to justify the additional testing and lengthening of the engine development process required by the regulation. Otherwise, the new regulation may amount to only a statement of intentions that requires closer coordination between developing, using, and supporting commands during engine development.

NEED TO IMPROVE CONTRACTOR INCENTIVES

In the past, the services have specified their performance requirements in contractual terms (that is, thrust, weight, and specific fuel consumption) and have paid for obtaining this performance. They, however, have not specified reliability, maintainability, and durability requirements in contractual terms and have not been willing to pay in time and money for achieving logistic goals when designated. Consequently, contractor performance in these areas has reflected the services' contractually expressed interests.

For example, in its TF34 modification program, the Air Force required the contractor to establish design lives for engine parts and reliability and maintainability objectives. These lives and objectives, however, were only goals. The contractor was not rewarded for meeting or exceeding the goals or penalized for not attaining them. The Air Force is still seeking to obtain the goals through its continuing TF34 CIPs.

Operational problems with the F100 and TF30 engines are also evidence of the Air Force's and Navy's failure to emphasize reliability and durability during full-scale development phases, especially when time and money constraints restrict their development efforts.

In summary, the services' emphasis on attainment of performance requirements before production has been a disincentive for contractors to reduce the engines' operational support costs when such actions would lower performance, increase development costs, or delay award of the production contract. The contractors' primary objective is to develop engines that will obtain production contracts. The production contract represents the bulk of program costs and in the past has provided a profit margin of about 12 percent. Once a production contract is awarded, the follow-on CIPs to obtain logistical goals are usually sole source and provide a profit margin of 7 percent or more. Retrofitting CIP improvements to production engines is additional profitable business.

Recent improvements

Recent actions for improving contractor incentives to develop more mature engines before production have included (1) new programs to increase competition, (2) negotiation of contract incentive awards, and (3) new emphasis on attaining structural integrity goals and requirements.

DOD representatives state that there is only one contractor who has experience in developing high-thrust (20,000 pounds) gas turbofan fighter engines. To increase competition, the Air Force and the Navy, under their joint F101DFE program, are funding a second contractor to develop an alternate engine for the F-14 and F-16 aircraft should the aircrafts' current engine CIPs fail to correct existing deficiencies. Also, preliminary planning for the joint ATE program contemplates three or more contractors to support concept formulation and two competing contractors during concept validation and into full-scale development.

In its F404 program, the Navy provided award fees up to $8 million for meeting and exceeding reliability and maintainability goals set forth in the development contract. The Navy has also negotiated reliability, durability, and maintainability incentives for the TF30 improvement program.

Because of problems with today's engines, the two services are emphasizing durability goals and requirements during development and are more willing to pay for achieving them. Improved definition of mission and usage requirements and improved testing methodology enable contractors to more

realistically design to the requirements and verify their attainment. Contractor performance, therefore, can be expected to respond to the services' new emphasis.

Operational warranties

In September 1978 the Air Force requested its contractors to submit detailed proposals for operational warranties on F100 and TF34 engines to be purchased. The two contractors submitted their proposals during the latter part of 1978, and the proposals were under study by the Air Force during 1979.

Navy officials believe the purchase of operational warranties will only serve to increase the cost of fighter engines. They point out that contractors will severely limit their financial liability and charge substantial sums for the limited warranties. These officials believe it makes better economic sense for the military to self-insure against engine problems with CIP funds.

Our limited information on the contractors' proposals tend to support the Navy officials' comments in the sense that costs are substantial in relation to the limited coverage. For example, one contractor submitted a warranty proposal costing about $7.6 million with the stipulation that the amount of coverage not exceed $9.5 million. The contractor's analysis of 100,000 flying hours showed that in the worst case situation, Government claims would probably not exceed $6.7 million.

Although the Air Force's initial requests for operational warranties may only be exploratory at this time, past studies have raised the question whether such warranties are possible without major changes and improvements in the Government's acquisition process. The problem is the inability of the Government and the contractors to define obligations, measure risk, and price it.

For example, as noted in the 1976 DOD Procurement Management Review report, the Air Force cannot maintain its right to make all technical and management decisions and then expect the contractor to accept the financial risks associated with these decisions. Also, commercial operational warranties are based on the airlines maintaining the engines using manufacturer-approved procedures, operating the engines using "standard" commercial operating practices, maintaining adequate maintenance and operating records available for the manufacturer's inspection at any time, and buying virtually all spare parts from the manufacturer at his catalog price.

On the other hand, when the above differences are not particularly material and the risks can be defined, measured, and priced, the engine manufacturer has been willing to propose operational warranties comparable to those offered commercial airlines. The few cases where commercial engines were proposed for military transport or cargo aircraft are examples, such as the JT8D engine in the C9A aircraft and the proposed reengining of the KC-135 with either the JT8D-209B or the TF33-P-101 engines.

New Air Force regulation

Air Force Regulation 800-30 states that performance (such as thrust, specific fuel consumption, and so forth), durability, and measures of merit required for an engine must be specified in the full-scale engineering development contract and subsequent production contracts. Before this phase is completed, engine objectives as stated in the contract must be demonstrated through the process of analysis, ground and flight tests, and accumulation of logistic and support data.

The regulation also provides that the development manager will publish a report which shows the trade-offs made between cost, durability, and performance. This report will be the basis for making a risk assessment in warranties in any future contract.

The regulation is a major step forward in the Air Force's attempt to give logistical considerations equal weight with performance requirements during development. Given the ever present cost and schedule constraints plus the limited capability for demonstrating achievement of logistical requirements during development, the issue is how well the provisions can be implemented.

CONCLUSIONS

Improvements in the engine acquisition process are being made to design and develop more mature engines before production. The services are trying to develop structural design and test criteria and are performing more meaningful durability-type tests during development and CIPs. However, the Air Force's efforts to transfer risks from the Government to the contractors through operational warranties is dependent upon the ability of both parties to define, measure, and price the risks transferred. This may only be possible in a limited number of cases.

The Air Force's new regulation requires logistical goals to be specified in the full-scale engineering development contract along with performance goals and to be demonstrated.

However, for the services to give logistic support requirements equal weight with performance requirements they must:

1. Bring technology up to the point that it is fully ready for systems application. That is, compromises between performance and supportability enhancements must be identified and understood.

2. Develop an engine management standard that defines the goodness and cost effectiveness of an engine that is acceptable to the developer, user, and logistician.

3. Establish an engine life cycle cost accounting-type data base to develop and validate life cycle cost models and to measure an engine's life cycle costs during its operational deployment.

4. Develop other data collection and analytical procedures for

   --realistic risk assessments,

   --design-to-cost studies,

   --reliability and maintainability assessments, and

   --true life cycle cost trade-off decisions.

   The latter includes a historical data bank on engineering changes, improved usage data, and improved techniques for analyzing structural engine designs.

The above improvements are interrelated and interdependent--failure to achieve one compromises the others. Although the services have generally recognized the need for the above improvements since 1975-76, progress in obtaining the improvements has been slow.

In general, the Air Force's new regulation outlines the actions needed but does not show how the actions will be taken and the improvements realized. Consequently, we believe that as the engine development programs continue to experience cost growth, schedule slippages, and performance degradation, logistical support considerations whose benefits are difficult to quantify and whose achievements are difficult and costly in time and money to demonstrate will continue to be secondary to performance goals. In our opinion, until the improvements are actually achieved, the cost effectiveness of an engine

will continue to be largely the product of time--the longer the engine is in service, the more its problems will be identified and resolved and the better the engine becomes.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

Over the past 10 years, a number of comprehensive studies have been made of the aircraft gas turbine engine acquisition process. These studies have made numerous recommendations for improving the management process. The services have implemented some improvements and are working and studying others to the extent that resources and policy direction permit. In general, the issue is less what should be done and more how and when will it be done?

In our opinion, the answer to the above question is dependent upon top-level policy direction, support, and commitment to an organized and disciplined approach to the structural design, analysis, development, production, and life management of aircraft gas turbine engines within DOD, the Navy and Air Force. Direction of propulsion development and production is now managed and controlled by a relatively large number of different groups in DOD and the services. These include the services' propulsion and material development laboratories and groups within the services' developing, using, and supporting commands. The groups have different priorities, budgets, and objectives. Effective direction and coordination of the groups' activities should improve effectiveness and continuity that have been lacking in the past programs.

Our review of past programs shows that new engine programs have generally achieved the operational performance objectives that justified their development initially. However, the developing services did not spend the time and money to achieve the engines' reliability, availability, maintainability, and durability (logistical) goals before production and operational use. Further, the services did not spend the time and money to achieve the logistical goals on modified engines that did not incorporate new technology and whose performance characteristics were known. Instead, CIPs were funded for this purpose after the engines were approved for production. This approach has resulted in low operational readiness, additional spare parts costs, and costly retrofits during the early operational periods. Historically, logistical improvements have been made through continuing CIPs and retrofit programs, after which the engines were considered mature.

During the past 5 years, however, logistical and operability problems, particularly with the F100 and the TF30 engines, have been longer lasting and much more costly in terms of operational readiness, spare parts, and retrofits.

The F100 and TF30 problems and their costs, which will continue into the mid-1980s and possibly longer, have attracted top-level interest and concern within the services, DOD, and the Congress. For example, in 1978 the Defense Appropriations Conference Committee report directed the Navy and Air Force to initiate an alternate engine program for the F-14 and F-16 aircraft should the F100 and TF30 CIPs fail to correct existing problems.

The increased visibility and awareness have resulted in greater emphasis on demonstrating operability and durability in the Navy's F404 development program and the services' recently initiated joint ATE program. The Air Force has responded with its new concept of engine development which was published on April 14, 1980, as Air Force Regulation 800-30, and both services have improved their durability testing methodolgy and related development procedures and practices.

The Navy, however, has to formalize its new concepts, procedures, or practices, and both services have to develop the standards and supporting data base and methodology needed to fully implement and justify their new development concepts.

Without these standards and the supporting data base and methodology, the time and the money needed to achieve high reliability and durability may not be available. In future programs, performance objectives will continue to be a major objective because of the services' need to maintain military superiority. As in past programs, performance objectives may continue to overwhelm reliability and durability goals simply because performance can be relatively well defined and measured during early phases of development whereas durability can only be predicted, not measured, before actual operational use.

As discussed in this report, some corrective actions to more fully develop engines before production have been and are being taken in current programs. However, based on progress to date, an organized and disciplined approach to the structural design, analysis, development, production, and life management of aircraft gas turbine engines is still far from being realized.

The 1976 Procurement Management Review team's report recommended that all engine studies of a general nature be terminated until the recommendations of all previous studies have been officially closed out. (See app. I.) A similar recommendation was made in the Scientific Advisory Board's Special Report on Turbine Engines in January 1976. We are noting these recommendations to reemphasize that the primary

issue is not what should be done, but how and when will it be done?

RECOMMENDATIONS TO THE SECRETARY OF DEFENSE

Therefore, to provide top-level understanding, support, and policy direction, we recommend that the Secretary of Defense delegate specific responsibility to an organization within his Office to direct and supervise the Air Force and Navy efforts to establish an organized and disciplined approach to the structural design, analysis, development, production, and life management of their aircraft gas turbine engines. We recommend that the designated organization be responsible for requiring the services to

--complete the formalization of their policies, principles, and procedures for engine acquisition management by way of regulations and other appropriate documents based on lessons learned from past programs, including appropriate recommendations from previous studies on the acquisition management process;

--establish a master plan for developing the standards, supporting methodology, data base, and analytical procedures needed to fully implement the policies and principles, and make the long and costly empirical and iterative engine development process more rational and analytical (data collection and analytical procedures are particularly needed for realistic risk assessments, design-to-cost studies, reliability and maintainability assessments, and for true life cycle cost trade-off decisions);

--realine funding priorities to expand and improve advanced development (technology demonstrator) programs in general and structural testing and development in particular; and

--coordinate their improvement efforts so as to enhance and encourage joint acquisition programs, such as the ATE program.

We also recommend that the designated organization closely monitor the F101DFE and ATE joint programs. The recently initiated ATE program could be used as a pilot program to test and refine the services' new engine acquisition management concepts and to further develop and refine data collection and analytical procedures needed to produce more mature and cost-effective engines before full-scale production.

Because of the magnitude of current engine problems and the criticality of engines in ensuring the success of aircraft systems, the Congress has expressed an increasing interest in the development and management of the Air Force's and Navy's aircraft gas turbine engines. During the past 2 years, the Congress initiated and appropriated moneys above the budget request to maintain an alternate engine program for Air Force and Navy fighter aircraft and to initiate durability-type testing of both services' advanced engine components and technology demonstrator engines. In 1979 the House Committee on Appropriations expressed concern for (1) more competition, (2) more complete development of engines' reliability, maintainability, and durability before production, and (3) innovations in management organization and procedures within DOD.

In its report on DOD's 1980 Appropriation Bill, the House Committee on Appropriations directed DOD to take those steps which may be required to elevate its propulsion office in the Office of the Under Secretary of Defense for Research and Engineering to a position of greater visibility and authority. The committee felt that such an office could provide the technological leadership and program support needed in the development of the next generation of large, high-thrust fighter engines. The committee stated its plans to assist DOD by undertaking a detailed investigation of the management structure within the services for aircraft propulsion systems. The committee's two other specific initiatives included (1) recommending additional funding to begin durability testing and (2) directing DOD to begin funding the design and fabrication of early prototype versions of the next generation of large, high-thrust engines in the fiscal year 1981 budget.

Because of the above interest, we recommend that the Secretary of Defense periodically report to the Congress its progress and problems in developing an organized and disciplined approach to the life management of aircraft gas turbine engines. In our opinion, the report should specifically address the impact on existing programs--CIPs, F101DFE, and ATE. The objective would be to provide the Congress with the information it needs to carry out its oversight responsibilities and to lessen its need to get more deeply involved in DOD's management of engine programs.

AGENCY AND CONTRACTOR COMMENTS

In commenting on our draft report (see app. II), DOD stated that the report "* * * reflects fairly accurately the management problems in the acquisition of gas turbine engines" and that DOD has already taken action to incorporate the proposed corrective actions into the DOD system for development and acquisition of new aircraft gas turbines. DOD did

not agree, however, with our recommendation that the Congress require DOD to periodically report its progress and problems in developing an organized and disciplined approach to the life management of aircraft gas turbines. DOD's position is that the current requirements for providing information to the Congress are sufficient.

DOD also seems to acknowledge that the requirements for providing information to the Congress have not been sufficient in the past. It reports that some of the serious difficulties with engines in service have resulted directly from failure to appropriate or budget funds necessary to adequately develop or adapt them for their intended uses. DOD adds that this report should recognize timely support will be necessary to preclude such problems in the future.

In our opinion, this report not only recognizes the problem, but recommends more effective communication within DOD and the Congress to correct it. We agree, however, that DOD's reportings of its progress and problems in developing an organized and disciplined approach to managing the development, acquisition, and maintenance of aircraft engines could be made part of the annual authorization and appropriation hearings.

One of two engine contractors contacted commented (see app. III) on our draft report. This contractor stated that in general, it accepts the majority of our conclusions. The contractor expressed doubts, however, that some of the solutions offered are entirely realistic or achievable. The most questionable, in its opinion, regards the availability of adequate funding early enough to fully complete the development of engines before their production or operational use. The contractor also pointed out that the scope of our study did not include some of the broader policy options and trade-offs that could be considered in engine development.

Related to this concern are questions the contractor raised concerning trade-offs in the acquisition of engines from a benefit risk standpoint.

We agree that the greatest challenge to adequately developing engines before their production and operational use are the ever present time and money constraints. We also agree that timeliness in responding to a projected threat may justify deviations from an optimal engine development approach and would increase the risks associated with the particular engine development. Our report, however, is geared toward the establishment of an organized and disciplined approach to the life management of aircraft gas turbine engines and not toward situations in which justifiable deviations can be allowed.

DOD'S PROCUREMENT MANAGEMENT REVIEW

OF

AIRCRAFT GAS TURBINE ENGINE

ACQUISITION AND LOGISTICS SUPPORT

(FEBRUARY 1976)

SCOPE

The Procurement Management Review of Aircraft Gas Turbine Engine Acquisition and Logistics Support was initiated by direction of the Deputy Chief of Staff, Systems and Logistics, Headquarters, the United States Air Force. The report presents the results of a 10-month study effort. The primary purpose of the effort was to (1) perform a comprehensive review of the policies, procedures, and practices used by the Air Force in acquiring and supporting aircraft gas turbine engines, (2) assess the current process in terms of its effectiveness in the areas of management, technology, development, acquisition, logistics support, and life cycle costs, and (3) where appropriate, develop recommendations for new or improved policies, procedures, and practices.

CONCLUSIONS

The major conclusions of the review were grouped into 12 categories.

1. Management decisionmaking process. Air Force decisions on engine matters are primarily aimed at achieving a real-time or near-term solution. The lack of a common criteria for determining the goodness of an engine, coupled with the lack of complete and accurate life cycle cost data, results in suboptimized decisions not based on total system costs.

2. Organization. The Air Force organization for engine management is fractionalized. Its stature is not commensurate with the importance of this subsystem. Many Air Force engine problems today are management-related problems.

3. Technology. Today, technology is oriented toward improving engine performance; however, there is a discernible effort to consider engine reliability, maintainability, and durability in early technology programs. Management attention and resources must continue to focus on performance technology if the United States is to retain its world technology leadership. At the same time, increased attention

and resources must also be devoted to maintenance technology to reduce future operating and support costs.

4. Procurement. Air Force engine procurement strategy is constrained by high technological and financial risks and a limited number of contractors. Numerous procurement strategies have been used over time with mixed results. Until the Air Force actually demonstrates, via funding and contractual requirements, a real desire to achieve greater reliability, maintainability, durability, and life cycle cost visibility, logistics economy will be slow in coming.

5. Development process. The engine development process is evolving and improving. The process suffers from time and funding constraints. State-of-the-art engine development programs invariably experience hardware failures and major setbacks. Engine development usually requires about twice the time needed for airframe development. If developed concurrently with the airframe, fully developed production engines will not be available to meet the system delivery schedule. It appears that all levels in the Government do not fully understand or accept these facts concerning the engine development process.

6. Testing. Engine testing is being tailored to more accurately reflect mission requirements; however, the full potential of analytical, ground, air, and operational engine testing has not been exploited.

7. Maintenance. A firm, realistic engine maintenance concept is not developed early enough in the process. The modular maintenance and on-condition maintenance concepts have been oversimplified and are not completely understood. At present, these concepts are not, and cannot be, implemented in the Air Force as conceived. In general, maintenance is driven by operational readiness and not life cycle cost considerations, and its efficiency suffers as a consequence.

8. Logistic support. Logistic support for engines is driven by production and operational readiness rather than overall or long-range cost considerations. Support is impaired by time and funding constraints.

9. CIP. The purpose and operation of CIP are not fully understood at all levels within the Government and industry. CIP, or a similar effort, is necessary for timely engine development/maturing and operational support; however, Government management of the effort should be strengthened.

10. Contractor performance. Engine contractors' performance has been a reflection of Government management emphasis. Air Force contracts contain precisely defined performance and schedule parameters, and contractors have performed well in these areas. In the less emphasized areas of reliability, maintainability, and durability, their performance has not been exceptional, especially when time and money constraints have restricted development efforts.

11. Commercial-military. There are basic differences between the commercial and military in engine development and procurement, inventory size, mission, route structure and stability, flying hour program, maintenance practices, and work force. These must be recognized and taken into account when assessing engine management policies and practices. Commercial engine activities are more cost oriented, and the airlines give more continuing high-level attention to efficient engine management.

12. Cost considerations. The entire engine management process is hampered by inadequate cost data. Current or near-term costs outweigh life cycle costs in most management decisions.

RECOMMENDATIONS

The report contains six major recommendations. All require direction from the highest levels of management within the Air Force to be implemented. The review team believes adoption of these six recommendations will remedy many of today's engine problems, minimize the number and scope of tomorrow's engine problems, retain U.S. leadership in gas turbine technology, and achieve a rational balance among performance, reliability, maintainability, durability, and cost. The recommendations are:

1. An Air Staff organization with corporate responsibility and accountability for propulsion be established. It would have the overall Air Force fiscal and policymaking responsibility for propulsion. The organization would be the focal point for all Air Force-related propulsion activities. It would serve as a centralized source of policy, direction, and visibility for overall propulsion system requirements, acquisition, and logistics support. It would be responsible for the funding and management of all CIP efforts throughout the entire life of all Air Force engine programs. The Air Staff organization should be of sufficient stature and have the necessary authority to carry out these responsibilities.

2. Base the transfer of management of the engine from Air Force System Command to Air Force Logistics Command on a level of "maturity" milestone rather than "at the earliest practicable date during the production phase" per Air Force Regulation 800-4, or "when the system/equipment is operational and the workload no longer requires development engineering" per Air Force System Command/Air Force Logistics Command Supplement 1 to Air Force Regulation 800-4.

3. The Air Force establish a realistic engine management policy regarding performance, durability, and cost. The degree to which the commercial approach to product support and warranties is desired must also be stated. Decisions at all management levels can then be made and evaluated on that basis.

4. A standard measure which defines the acceptability of an engine be developed for use by the Air Force Systems Command, Air Force Logistics Command, and the using commands. This measure would address cost, engine performance, and operational readiness and be used to indicate the goodness of an engine. In conjunction, an engine life cycle cost accounting-type data base should be established. A current engine program should be used as the pilot program to develop the data collection and analysis procedures that will enable the Air Force to make true life cycle cost trade-offs and decisions in the future.

5. Management support be given advanced engine development programs, such as APSI and ATEGG, modernization and increased use of Government engine test facilities, and the Aeronautical System Division's new engine development concepts. Affirmation in the form of increased funding is required.

6. All engine studies of a general nature be terminated. Until the recommendations of all previous studies have been officially closed out, no further general-type studies should be initiated. Manpower resources should be concentrated on current day-to-day work and future planning. Only studies directed at solving specific technical problems should be permitted.

The organization of Recommendation No. 1 would be responsible for establishing the maturity level for transfer of engine program management responsibility; developing the Air Force engine management policy; overseeing the development of the engine goodness/management measure and concepts, advanced development programs, and Government engine test

facilities; and implementing and closing out all study recommendations. Should Recommendation No. 1 not be adopted, then the Propulsion Review Board should be officially chartered by Headquarters, United States Air Force, and directed to accomplish the remaining recommendations.

Other areas for improvement came to the attention of the team. Some were quite significant. However, it was the conclusion of the team that for the most part these areas were merely symptoms and not root causes. Granted, the Air Force will benefit when they are remedied, but prevention of similar "symptoms" in the future requires implementation of the six major recommendations.

APPENDIX II

THE UNDER SECRETARY OF DEFENSE

WASHINGTON D C 20301

RESEARCH AND
ENGINEERING

24 JUL 1980

Mr. J. H. Stolarow
Director, Procurement and
Systems Acquisition Division
U. S. General Accounting Office
Washington, D. C. 20548

Dear Mr. Stolarow:

The draft report dated May 29, 1980, "Are Management Problems in the Acquisition of Aircraft Gas Turbine Engines Being Corrected?" (GAO Code 951469) (OSD Case #5336A) has been reviewed and the following comments are forwarded. Overall, the report reflects fairly accurately the management problems in the acquisition of gas turbine engines. As you know, the area addressed by this report has been the subject of continuing studies by numerous DoD, Congressional and independent groups over the past several years. No fewer than sixteen studies, assessments and investigations have been conducted during the 1970-1980 time period to review aircraft engine development, management and acquisition. For the most part, the findings and recommendations of these efforts were similar and have formed the basis for a new engine development, management and acquisition policy within the DoD. As pointed out, the "lessons learned" are known and so are the corrective actions which should be taken. I believe that the DoD has already taken actions to incorporate the proposed corrective actions into the DoD system for development and acquisition of new aircraft gas turbines.

The one recommendation in the report with which the DoD does not agree is the proposal that Congress require the DoD to periodically report its progress and problems in developing an organized and disciplined approach to the life management of aircraft gas turbines. It is felt that the present requirements of the DoD and the Military Departments to provide technical management information to committees of the Congress are sufficient to meet the purpose intended by the GAO recommendation.

Some of the serious difficulties we have experienced with engines in service have resulted directly from failure to appropriate or budget the funds necessary to adequately develop or adapt them for their intended uses. The report should recognize that timely support will be necessary to preclude more problems of this kind in the future.

Our detailed comments are presented in appendix A. [See GAO note.]

Sincerely,

William J Perry

Enclosure

GAO note: Detailed comments have been incorporated into the body of the report.

PRATT & WHITNEY AIRCRAFT GROUP

GOVERNMENT PRODUCTS DIVISION

William C. Missimer
Executive
Vice President

P. O. Box 2691
West Palm Beach, Florida 33402

25 June 1980

Mr. J. H. Stolarow
Director, Procurement and Systems
Acquisition Division
United States General Accounting Office
Washington, D. C. 20548

Dear Mr. Stolarow:

First, let me congratulate you on your new position as the Air Force Auditor General. I see that you are the first civilian to hold this key position.

I want to thank you for the opportunity to review the draft of the report "Are Management Problems in the Acquisition of Aircraft Gas Turbine Engines Being Corrected?" dated May 1980. In general, we accept the majority of the conclusions that this study has reached, but must express serious doubts that all of the solutions offered are entirely realistic or achievable. The most questionable is the availability of adequate funding early enough to fully complete the development of engines before their production or operational use. That doesn't imply that these goals are not worth striving for, and we intend to do our part in supporting the overall DoD program to improve in all areas of engine acquisition.

We realize that in undertaking a study of this kind that there is a cutoff or time limit of data that can be included. However, the reference to "present engine problems" is in fact describing the situation from one to five years ago, and the performance of the F100 and TF30 engines has progressed significantly since then. In that respect, it is suggested that data be referenced with the appropriate date for the time period which that data represents. [See GAO note.]

In my previous letter of 31 March 1980, we addressed to some extent the overall concept for the acquisition of engines from a benefit/risk standpoint. Unfortunately, the scope of your study does not include some of the broader policy options and tradeoffs that could be considered in engine development, but reaches for solutions to fix the current process and problems. For example, should not some consideration be given to the system which has been used for the F100 engine which may be the

GAO note: Report has been changed to accurately reflect the time period for the engine problems cited on pp. 10 and 11.

UNITED TECHNOLOGIES

APPENDIX III

Mr. J. H. Stolarow -2- 25 June 1980

optimum from the standpoint of timeliness, countering a projected threat, and balance of power to permit diplomacy to work to maintain peace and defend U.S. interests and principles? The overall picture of aircraft engines acquisition should be examined from the viewpoint of where do I want to be at selected periods in the future, i.e., how many new engine starts should there be for what type and size of engine in a score of years. The greater number of starts, the smaller performance increments for each is logical; the fewer the number of starts, the larger the performance achievement must be and the greater the associated risks. Experience of the last two decades surely disregarded the advantages of these considerations. Hopefully, the changes now being considered for the gas turbine development programs will help correct the problems and deficiencies which your study documented.

I believe there is reason for optimism, since there are many benefits that can occur from the results of your study and recommendations. Considering the scope and purpose of the report, I consider that your staff deserves a compliment that is well earned.

Sincerely,

Bill Missimer

W. C. Missimer
Executive Vice President

(951469)

END

DATE
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